ARI Research Note 88-57

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AD-A197 429

Training Effectiveness and Cost Iterative Technique Volume II: Cost Effectiveness Analysis

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Consortium of Washington Area Universities

for

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Research Institute for the Behavioral and Social Sciences

July 1988

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Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A-1		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

ADA197929

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS - -
2a. SECURITY CLASSIFICATION AUTHORITY - - 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE - -	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) - -	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Research Note 88-57
6a. NAME OF PERFORMING ORGANIZATION Consortium of Washington Area Universities 6b. OFFICE SYMBOL (If applicable) - -	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences
6c. ADDRESS (City, State, and ZIP Code) 1717 Massachusetts Avenue, NW: Suite 101 Washington, DC 20036	7b. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600
8a. NAME OF FUNDING / SPONSORING ORGANIZATION see 7a 8b. OFFICE SYMBOL (If applicable) - -	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA903-82-C-0383
8c. ADDRESS (City, State, and ZIP Code) - -	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: 6.30.07.A PROJECT NO.: 2Q263007A795 TASK NO.: 3.4.4 WORK UNIT ACCESSION NO.: 3.4.4.R1

11. TITLE (Include Security Classification)
TRAINING EFFECTIVENESS AND COST ITERATIVE TECHNIQUE
Volume II: Cost Effectiveness Analysis

12. PERSONAL AUTHOR(S)
Arvil V. Adams and Margaret L. Rayhawk (George Washington University)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 2-86 TO 1-87	July 1988	104

16. SUPPLEMENTARY NOTATION John J. Kessler, contracting officer's representative. Report refers to VOLUME I TRAINING EFFECTIVENESS ANALYSIS (TECIT) by I. Goldberg.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	~~Cost and Training Effectiveness Analysis (CTEA)~~ Transfer Effectiveness, Cost Effectiveness Training Technologies, M1 Abrams Tank, MicroTICCIT

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This research note discusses an important issue, the training of soldiers in the use of a weapon system, which is important to the operational cost and success of the system in the carrying out of its mission. Cost and Training Effectiveness Analysis (CTEA) models formalize the process of choosing among alternative training technologies by comparing the cost and training effectiveness of these technologies. In this report, an economic framework is presented for integrating cost and training effectiveness data for CTEA studies. The framework builds on transfer effectiveness models and offers a model for the effectiveness of cost-minimizing training technologies. The model is particularly well-suited to the selection of training technologies for tasks that are trained on weapons systems whose operation is costly or life threatening. The research note shows how cost data would be developed for the model in evaluating computer-assisted instruction as a training technology for the M1 Abrams tank.

Keywords: Army training, Training devices, Transfer of

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL John J. Kessler	22b. TELEPHONE (Include Area Code): 202/274-8694 22c. OFFICE SYMBOL: PERI-I

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

Training, [illegible]

ACKNOWLEDGMENTS

This report was prepared with support from the Consortium of Washington Area Universities and the Army Research Institute for the Behavioral and Social Sciences. We are indebted to a number of individuals who have made important contributions to the study. We wish to especially thank the Army Research Institute Advisory Committee, including D. Bruce Bell, Stanley F. Bolin, Hyder Lakhani, and John J. Kessler, who offered advice and counsel throughout the study and who served as a constant sounding board for our ideas. A special note of appreciation is offered to John J. Kessler who served as the Contracting Officer's Representative. Dr. Kessler provided valuable assistance throughout the effort and made many useful suggestions for improving the final report.

During the course of the study, several individuals at the Ft. Knox Armor Center provided us with access to specialized literature and insights into the conduct of training using computer-assisted instruction, training devices, and simulators. These insights have enriched the study enormously. Among others who contributed in this respect, we want to especially thank John A. Boldovici, Don F. Haggard, and Don M. Kristiansen. We also wish to express our appreciation to those who read an earlier version of this report and offered suggestions for its improvement. In this regard, we wish to thank Angelo Mirabella (ARI), Jesse Orlansky (Institute for Defense Analysis), and Henry Solomon (The George Washington University). Finally, from our own staff, we wish to thank Eileen McKeon for her assistance in the production of this report.

As is customary, the views expressed in this study are our own and do not necessarily reflect the official views of the U.S. Army. We naturally assume responsibility for any errors or omissions.

Arvil V. Adams
Margaret L. Rayhawk

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CHAPTER ONE
An Economic Framework for the Integration of Cost and Training Effectiveness Data in Choosing How To Train*

INTRODUCTION

This report is part of a long-range Army Research Institute (ARI) program to assess the efficiency with which the Army trains its weapon system maintainers and operators. Previous efforts by ARI and other laboratories have focused on ways to assess training effectiveness (e.g. Adams and Rayhawk, 1986; Goldberg, 1986; Knerr, et al, 1983; Klein, 1985). The current effort combines cost and investment analysis with training measures to build a model which can help the Army choose the type and amount of training needed to "produce" different kinds of skills. The effort also demonstrates how the model can be used by applying it to tank gunnery training at Fort Knox.

BACKGROUND

Training soldiers in the use of a weapon system is important to the operational cost and success of the system in carrying out its mission. This training may take place using a variety of methods ranging from classroom instruction, supported by various media, to the use of computers, simulators, training devices, and actual field exercises with the weapon system.

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* This chapter is prepared by Arvil V. Adams

These methods, described as training technologies, may be used individually or in combinations to train for specific tasks or combinations of tasks. The choice of how to train, and therefore, which technology or combination of technologies to use, rests with the effectiveness of the training in preparing the soldier to perform his duties and the cost of the training. The selection of a least-cost technology in the interest of cost savings may result in unacceptably low levels of training effectiveness. At the same time it may not be possible to select the most effective training technology to satisfy a training requirement without regard to differences in cost. Cost and training effectiveness, therefore, must be considered jointly in the decision of how to train.

Cost and Training Effectiveness Analysis (CTEA) models formalize the process of choosing among alternative training technologies by comparing the cost and training effectiveness of the alternative technologies. The choice of how to train is determined by comparing the net benefits of training associated with each technology and choosing the technology or combination of technologies which maximizes these net benefits. As shown in Figure 1.1, taken from Orlansky (1985), clear gains in net benefits are evident where a technology provides additional training effectiveness for the same cost, or the same effectiveness at less cost. Alternatives that lead to the same costs and effectiveness, on the other hand, allow the cost analyst to be indifferent as to which technology is adopted.

		EFFECTIVENESS		
		Less	Same	More
COST	Less	?	+	+
	Same	-	?	+
	More	-	-	?

Adopt +

Reject -

Uncertain ?

FIGURE 1.1 Decision Diagram for Evaluating the Relative Effectiveness and Cost of Two Methods of Training

The more difficult case arises where costs and effectiveness both increase or decrease. The decision of how to train in these cases depends on the relative change in costs and effectiveness and the net benefits derived therefrom. CTEA models, as found in the literature, do not provide for the direct measurement of these benefits. (A.V.Adams and M.L.Rayhawk, 1986) To do so requires that the measures of training effectiveness and cost be expressed in terms that can be compared with each other. Instead, the measures of training effectiveness used frequently involve

indicators of performance in training, or actual measures of performance on the task for which the training is provided. The measures do not express the benefits of the training in monetary terms for comparison with costs to determine the net benefits of the training. As a result, when a training technology leads to an increase or decrease in both training effectiveness and cost, there is no direct means to determine the net gain or loss of benefits associated with use of the technology. In this situation, CTEA models do not provide a ready answer to the question of how to train.

In this chapter, we introduce a CTEA model that, instead of attempting to maximize the net benefits of training, seeks to minimize the cost of achieving a specific standard of task performance. As such, the model circumvents the problem of non-commensurate benefit and cost measures. The approach taken builds on the earlier work of S.N. Roscoe (1971, 1972) and J. Orlansky (1985) and introduces an economic framework for the integration of cost and training effectiveness data. The model focuses on the economic value of time saved in training on a weapon system by substituting less expensive time on an alternative training technology. With this focus, the model is especially well-suited to the selection of training technologies for tasks that are trained on weapon systems whose operation is costly or life threatening. Where expensive training technologies are employed in non-systems training, the model can also be used to evaluate less costly alternative training technologies.

The model is introduced with application to training on the M1 Tank. The M1 Tank is representative of weapon systems which are expensive to use in training. The model is developed for use by the Training Technology Field Activities (TTFA) at the Ft. Knox Armor School. The TTFA at this site combines personnel of the Training and Doctrines Command (TRADOC), the Army Research Institute (ARI), and the Armor School in the evaluation of alternative training technologies for the M1 Tank. The emphasis of the TTFA's is on computer-assisted instruction, training devices, and simulators. With suitable methodologies available for the estimation of training effectiveness and cost data, the model is intended for CTEA studies during all development stages of a weapon system's life-cycle, however, as illustrated here for the M1 Tank, it is most suitable for use in the fielding phase.

We begin this chapter with a review of the tools of cost-benefit and cost-effectiveness analysis as used in the decision of how to train and the economic concepts of cost employed therein. The CTEA model is then introduced with its data requirements. In the chapter to follow, we illustrate how cost data are developed and used with transfer effectiveness data to conduct a CTEA study of computer-assisted instruction as an alternative training technology for the M1 Tank.

THE ECONOMICS OF TRAINING

Cost-Effectiveness Analysis

The decision to train has generally been made by the time the CTEA analyst enters the picture. The issue before the

analyst is not whether to train, but how to train. By one means or another it has been determined that the benefits of training exceed the costs and the issue is one of finding a training technology that maximizes the difference between the two, benefits and costs. Benefit-cost analysis is typically used by the economist for this purpose, where the benefits of the training can be monetized and compared with costs. The difference, representing the net benefits of training, can be compared for different training technologies. The technology selected is that which maximizes these benefits. In some instances, however, it is difficult to quantify the benefits of training in monetary terms commensurate with those of costs. The ability to effectively engage and destroy an enemy tank has a direct benefit to those seeking protection from an aggressor force. Yet, the measurement of this benefit in dollars presents a difficult methodological problem.

In instances such as the tank example where the benefits of training cannot be expressed in terms commensurate with those of costs, cost-effectiveness analysis is used. Using this tool, benefits are expressed in units of output, for example, scores on tests, number of program graduates, or measures of on-job-performance. In the illustration above, an example of an on job performance measure might be the number of tanks destroyed or disabled. The problem encountered in using this tool for decision making is the assignment of weights to effectiveness measures. For example, how much is an increase in an exam score worth? What value can be attached to an

increase in the number of program graduates? What is the value of an additional tank destroyed? These questions are important in determining if a more expensive <u>and</u> more effective training technology is worth the additional cost. In benefit-cost analysis the answer is given by using market measures of the output's value. In cost-effectiveness analysis the weighting of the output is often left to the decision maker's subjective judgment. The weighting problem is even more complex where the training has multiple objectives.

<u>CTEA and Cost-Effectiveness Analysis:</u> CTEA is a variation of cost-effectiveness analysis given that measures of training effectiveness are not expressed in terms commensurate with those of training cost. The measures of training effectiveness chosen are many and varied. Ideally, they measure performance in the task as related to the training process. Intermediate measures of effectiveness are also used. Instead of measuring performance in the task, the number of program graduates may be used or measures of cognitive achievement gathered as intermediate indices of the benefits of training. These measures are treated as predictors of the trainee's increased productivity in the task to which the training applies. The problem, as described above, comes in attaching weights to these measures in comparing the training effectiveness of alternative training technologies. The problem exists in comparisons where training effectiveness and costs both increase or decrease. In all other instances, as described above in Figure 1.1, the change in net benefits is apparent.

Training costs play an important role in CTEA alongside training effectiveness. The determination of these costs is a multidisciplinary process. Psychologists and training developers, for example, are involved in the specification of training resource requirements as are engineers in the design and development of specialized resources. The tools of economics are employed in valuing these resources. The cost perspective taken in CTEA is that of the training organization, the Army, rather than the cost perspective of the individual or society. These perspectives may each lead to different cost estimates. The soldier who receives training that is paid for by the Army incurs no direct cost. The Army, however, does and would include this cost in its selection of a training technology. On the other hand, the Army may use publicly owned land for training maneuvers for which it incurs no direct cost of ownership. It would ignore this cost in its decision making even though society may incur a cost in terms of the foregone alternative uses of the land.

In addition to focusing on the cost to the Army, CTEA cost models further adopt an incremental cost perspective. That is, as generally applied, CTEA cost models focus on the resources that are unique to each technology and exclude the resources that are common to each alternative. For example, classroom space would be required for lecturer and computerized training technologies. The cost of this space, to the extent it is required by both technologies, is excluded in the CTEA comparison of the two technologies. On the other hand, unique

costs such as climate control measures for computers are included in the comparison. These unique costs determine whether one technology is more or less expensive than another. The incremental cost perspective differs sharply from budgeting and life-cycle cost perspectives which include the shared costs. As a consequence, CTEA cost estimates, which include only the unique cost elements of each technology, will underestimate the budget and life-cycle costs of a training technology.

Cost Concepts in CTEA

Fixed and Variable Costs: The CTEA cost analyst will normally be given a set of training technologies which have been determined as appropriate to training for a specific task and asked to compare these technologies in terms of their cost. Simultaneously, a psychologist may be asked to compare these technologies in terms of their training effectiveness. The results will subsequently be combined in the CTEA exercise to select a training technology which maximizes the net benefits of training. Along with the set of training technologies, the cost analyst will be given the resource requirements of each technology. The task of the cost analyst is to factor out the resources common to all technologies and attach a cost estimate to each of the remaining resources for comparison purposes. The first step in this process is to distinguish between fixed and variable resources.

Fixed resources define the scale of the training to be done. The costs incurred in fielding a weapon system are

typically viewed as fixed costs and include costs incurred during development and procurement phases of a weapon system life-cycle. Once acquired, the quantity of these resources cannot be easily changed during the period of training. Classroom space, the number of computer stations, the number of tanks available for training are all examples of fixed resources. Over time, of course, the quantity of these resources can be changed as new classroom space can be constructed, additional computer stations purchased, and tanks acquired. In any given training period, however, these resources are treated as fixed in quantity and thereby determine the scale of training possible in that period. The cost of these resources is also fixed during the training period. Because, by assumption, the quantity of these resources cannot be changed during the training period, their cost must be paid regardless of whether or not they are fully utilized.

Fixed resources are contrasted with variable resources whose quantity can be changed during the training period. The number of instructors employed, the media materials available, the time spent by students in a computer lab are examples of resources whose quantity can be varied with greater ease during the training period. To this extent they are described as variable resources and their cost is a variable cost. Variable costs are typically associated with the operation of a fielded weapon system and include costs incurred during the operations and support phase of a weapon system life-cycle. The amount of variable resources employed determines whether or not the fixed resources are fully utilized. The Army may have the capacity in

fixed resources for training 100 noncommissioned officers a year as M1 tank commanders, but choose to employ variable resources sufficient to train only 75 such officers. In any given training period, economic theory holds that the benefits of training must at least equal the cost of the variable resources employed, or it will not pay to train. Any benefits above the variable cost will offset the cost of the fixed resources. Over a longer period, the benefits must be large enough to pay for fixed and variable resources for training to occur.

Opportunity Costs: What is the real cost of the resources employed in training? The economist answers this question by using the concept of opportunity cost. The cost of any resource used in training is the value of the foregone output of this resource in its next best alternative use. Using the resource in training precludes its use in other production activities. The value of these foregone activities defines the opportunity cost of using the resource in training. For example, a classroom instructor training individuals in the techniques of repairing an M1 tank might alternatively be employed full-time in the repair of such tanks. The opportunity cost of the time spent in the classroom, as such, is measured by the value of the foregone repair services. In a market economy, the value of these services is the wage paid the service technician. The cost of using the individual's time as an instructor is measured by what the market would have paid for his time as a service technician.

The key to the measurement of the opportunity cost of a resource is the presence of a market economy. The invisible

hand of the marketplace will establish the value of a resource. To attract a resource to any production activity, the producer must at least pay what this resource can earn in its next best alternative use. Thus, the opportunity cost of a resource used in training is defined in the marketplace by the value of the resource in its best alternative use. In a non-market economy, determining the opportunity cost of a resource is more difficult. The wages paid a draftee, for example, prior to the all-volunteer force did not reflect the opportunity cost of this resource, since his market options were restricted during the period of induction. Even now, however, wages alone may not accurately measure the soldier's opportunity cost to the extent that non-wage benefits in the Army exceed those in the civilian sector. Measuring the opportunity cost of a resource, even with a market economy present in this instance, may involve art along with science.

Valuing the resources employed in training in terms of their opportunity cost, while appropriate from an economic perspective, will nevertheless lead to possible differences in cost estimates based on accounting concepts. The latter rely on historical costs. Depreciation charges based on the historical cost of a resource may bear no relationship to the current market value of the resource in an economy with unstable prices. In an inflationary period, for example, depreciation charges for classroom space built several years earlier will not accurately reflect the replacement cost of this space. The charge for this space, if based on historical costs, will

understate its real economic value. Accounting concepts also ignore the implicit cost of resources owned by the producer. In the example above, if the Army owns the classroom space, the cost accountant does not consider the opportunity cost of the undepreciated portion of this space. Keeping this capital in place for future use is not treated as a direct cost, although from an economic perspective, the foregone output of this capital is a real cost of maintaining the resource. The implicit cost problem is restricted to producer-owned resources.

Sunk Costs: Sunk costs are those fixed costs that cannot be recovered in the long run through liquidation or other means. An example of a sunk cost would be the research and development costs of a new training device. The product of the research and development effort, to the extent that it is specialized and its use limited to the Army, could not be sold and the cost recovered. In some instances, where a product of research and development can be used by others, the Army may be able to license the use of the product and recover some of its fixed cost. In all other situations, however, research and development costs can be treated as sunk costs. Other examples of sunk costs may include the purchase of a site license for the use of software in computer-assisted instruction, the construction of a uniquely configured facility whose use is limited to training, and other capital goods which have no use except in training.

The key in all these examples is the absence of an alternative use for the fixed resource to which the resource can be converted

and its cost recovered in part or whole. Sunk costs are important to CTEA involving fielded weapon systems and training technologies. Sunk costs, for example, are not a factor in comparing alternative training technologies for a new weapon system. The alternative technologies in this case start on an equal footing with none of the resources yet acquired and treated as sunk costs. Sunk costs may be a factor, however, when comparing a fielded training technology with a new training technology. The fielded training technology, because it may include sunk costs, gains an advantage in comparison with a new technology where none of its resource requirements are treated as sunk costs. The historical research and development costs of the fielded training technology, for example, can be treated as a sunk cost in the CTEA study and ignored in net benefit comparisons. For the new technology, however, research and development cost must be included, since, until spent, these resources can be programmed to alternative uses. Their opportunity cost, as such, is greater than zero.

Residual Value: Capital goods used in training may have a life that extends beyond the expected life of the weapon system or technology for which the training is provided. The latter may be used to define a planning period for training, a period during which resources must be organized and training provided. In cases where this occurs, the residual value of these capital goods at the conclusion of the planning period must be subtracted from the cost of training to isolate the resources actually used in training. The value of this residual is determined by

the productivity of these resources in their alternative uses at the conclusion of the planning period. This residual value is determined in a market economy by the price assigned to the resource as a used capital good. For example, at the conclusion of a planning period, a computer may retain value as a used capital good. This value should be determined and subtracted from the original cost of the computer to account for the cost of the capital actually used in training. Capital goods which represent sunk costs, by definition, have no alternative uses nor market value at the conclusion of the planning period for training. The residual value of these resources is zero.

The Army may employ a variety of resources in training whose residual value cannot be easily determined in a marketplace. An example might be classroom space located on post, built and owned by the Army. The alternative uses of this space may include administrative functions or even other types of Army training activities. To the extent the use of these resources is restricted to alternative Army uses, there exists no market-determined price for the residual value of these resources. In this situation, the analyst is left without a market measure of the opportunity cost of the resources employed in training. The solution in the costing exercise may require the use of an amortized historical cost as a proxy for the market measure or, if available, the market value of comparable space elsewhere. The older the space involved, of course, the less useful the historical cost is as a measure of the resource's opportunity cost.

Nominal Cost and Real Cost: The purchasing power of the dollar may change over time. In recent years, inflation has substantially reduced the purchasing power of the dollar. Training resources purchased in earlier years would cost more today due to this change in purchasing power. In expressing the cost of training resources purchased at different points in time, one may express these costs in dollars unadjusted for changes in purchasing power, that is, nominal costs, or in dollars adjusted for these changes. The latter represent real costs. The former are important from a budgeting perspective to express the dollars that are required for expenditures over time. The latter are important in comparing alternative training technologies whose resources are acquired in different time patterns. To determine if one technology requires more resources than another, the dollar units in which these resources are measured must be adjusted for differences in purchasing power.

Costs and the Time Value of Money: Not only must adjustments be made for changes in the purchasing power of money, adjustments must also be made for the time value of money in comparing alternative training technologies whose resources are acquired in different time patterns. A technology that requires a dollar be spent a year from now cannot be compared with an alternative that requires a dollar be spent today. The two are not equal in cost since an amount less than a dollar can be set aside today for the first technology and invested to yield a dollar a year from now when required. In terms of their present value, the first technology is less expensive than the second.

The return on this investment represents the time value of money. Historically, the time value of money has been about 3 percent with variations about this number. A market measure of this value can be determined at any point in time by subtracting the inflation rate from the return on long term government bonds. The difference reflects the amount of real return investors require for deferring the use of their dollars until the maturity of the bonds. This difference may be biased to the extent that estimates of future inflation differ from the current inflation rate.

The process of adjusting resource costs incurred at different points in time is called present value analysis. Future costs expressed in real terms are adjusted for the time value of money. These costs are expressed in present value terms and represent the sum of money that would have to be set aside today to yield enough to pay the future cost of the training resources. The time value of money used to determine this sum is called the discount rate in present value analysis as shown below.

$$PV = K_t/(1 + r)^t$$

PV = Present Value of a Capital Outlay

K_t = Capital Outlay in time t

r = Discount Rate

t = Year (1,2,...,n)

Changes in this rate can materially affect estimates of the present value of future training costs. For this reason, a range of rate estimates may be used to illustrate the sensitivity of the present value of future training costs to the discount rate used.

Where future costs are expressed in nominal terms, the discount rate may be modified to include an estimate of future changes in the dollar's purchasing power and the time value of money. A market measure of this rate can be found in the rate paid on government bonds with maturities that match the expected life of the training resources purchased.

The Department of Defense requires that future resource costs be expressed in real terms, that is, in constant purchasing power dollars. When this is done, the costs must still be adjusted for the time value of money. In at least two cases, the latter adjustment can be avoided. In the case where the planning period for training is brief, perhaps not more than three years, present value analysis will not materially affect the conclusions reached in cost comparisons of alternative training technologies. Also, where the pattern of resource costs incurred over time is similar for alternative technologies, the conclusions will not be affected by the use of present value analysis. In addition to expressing resource costs in real terms, the Army is also required by the Department of Defense and the Office of Management and Budget to use a 10 percent discount rate. Since constant dollars are being used, the rate represents an adjustment for the time value of money. This rate is inordinately high.

Historically, the time value of money has fluctuated around 3 percent. In the 1970's the difference between the return on long term government bonds and inflation actually yielded a negative real return on savings. More recently in the mid-

1980's this difference has been as high as 7 percent. Currently, with the yield on 30-year Treasury bonds at roughly 7.5 percent and inflation around 4 percent, this market measure of the time value of money is approaching its historical average of 3 percent. At no point in recent history has the time value of money been as high as the 10 percent discount rate required by OMB. If future costs were expressed in nominal terms, this rate would still be too high to adjust for changes in purchasing power and the time value of money. The appropriate discount rate would be much closer to the market determined rate on long term government bonds of 7.5 percent. The use of the required 10 percent discount rate in today's economic climate leads to a bias in favor of training technologies with costs concentrated in the future. Sensitivity analysis using different discount rates will illustrate the importance of the discount rate chosen.

THE INTEGRATION OF COST AND TRAINING EFFECTIVENESS MEASURES

The Problem

CTEA cost models establish the resource requirements of alternative training technologies, value these resources in terms of their opportunity cost, and adjust this value in real terms for the time value of money where necessary. The results, representing the cost of alternative training technologies, are then linked with the measures of training effectiveness to select the technology which maximizes the return on investment in training. The latter step is made difficult by the failure of CTEA models to measure training effectiveness in terms commensurate with that of cost. Where a univariate measure of

training effectiveness is employed, such as the number of tanks destroyed, the gain in net benefits from a training technology which produces higher levels of effectiveness for the same cost or the same level of effectiveness for less cost is self-evident. The problem becomes more complex, however, where multivariate measures of training effectiveness are employed or where effectiveness and costs both increase or decrease together.

Where multivariate measures of training effectiveness are employed, weights must be assigned to the various training effectiveness measures to determine the net gain or loss of benefits associated with alternative training technologies. Volume I addresses this problem in its discussion of multi-attribute utility (MAUM) analysis. Similarly, weights must be assigned to univariate measures of training effectiveness to rationalize if the marginal benefits of increased effectiveness offset the marginal increase in cost, and vice-versa where both effectiveness and cost decrease. The failure of CTEA models to express measures of training effectiveness in monetary terms commensurate with those of cost forces the analyst in all but the unequivocal cases mentioned above to present the results of the exercise in a form where the decision maker can assign the required weights and draw the conclusions which follow from the exercise. The decision, then, as to how to train becomes a command decision subject to the weights used for training effectiveness.

The early work of Stanley Roscoe (1971, 1972) involving transfer effectiveness measures, extended by Jesse Orlansky (1985), provides a path around this problem in CTEA models. The approach taken requires the analyst to establish a level of skills and knowledge to be accomplished through training. Alternative training technologies are then compared in terms of the cost required to train to this criterion. By establishing the level of training effectiveness required, this approach avoids the variable effectiveness-variable cost optimization problem. It is, simply stated, a cost minimization approach given the desired production level of skills and knowledge. Once the decision of how much to train has been made, this approach provides a useful methodology for choosing how to train, emphasizing efficiency in the selection process.

The Transfer Effectiveness Ratio

Roscoe's approach is particularly suited to the selection of training technologies for tasks that are trained on weapons systems whose operation is costly or life threatening. Examples of these systems include aircraft, ships, and tanks. Flight simulators have long been used as an alternative technology to that of training in the aircraft. Once a task and a standard of performance are determined, the Transfer Effectiveness Ratio (TER) can be used to identify those tasks for which it is more cost effective to train on the simulator than in the aircraft. Roscoe's approach can be applied to any training technology which purports to save time in training directly on a weapon system. The M1 Tank is an expensive weapon system to

operate and use for training. The TER, as such, is well suited to determining if various training devices, including computer-assisted instruction, can be used to achieve specific standards of task performance on the M1 at a cost which is lower than that of training on the weapon system itself.

The TER, as introduced, measures the amount of flight time saved as a function of the time spent in a simulator. It measures how well training on a flight simulator transfers to performance in the aircraft. Defined in more generic terms the TER is expressed as follows:

$$TER = (W - W_d)/D$$

W = Training Time to Criterion on a Weapon System Without Using an Alternative Training Technology

W_d = Training Time to Criterion on a Weapon System Using an Alternative Training Technology

D = Time on the Alternative Training Technology, e.g. training device, simulator, computer-assisted instruction

The numerator of the TER expresses the amount of training time saved in training to criterion on the weapon system as a result of substituting a training device, or other training technology. The denominator represents the time spent using the alternative technology. Several studies employing this measure

are reported in Orlansky (1985). Orlansky points out that the measure's use has thus far been limited to flight simulator training. Training technologies which yield positive values for this ratio indicate that time spent on the training device or alternative technology results in time saved in training on the weapon system. In both cases--training on the weapon system only and training on the weapon system after training with the alternative technology--the objective is to determine how much time on the weapon system is required to reach the required skill level. If successful, time on the alternative technology will reduce the time required on the weapon system to reach this skill level.

Where time on the alternative technology is expressed in hours, the TER can be interpreted as the average number of hours saved in training on the weapon system for each hour on the alternative technology. The value of saving time on the weapon system, of course, depends on the relative cost of this time to that on the training device or other technology. Roscoe's approach, therefore, requires the determination of this relative cost. The cost of time on the weapon system in relation to that on the alternative technology is expressed through Roscoe's Operating Cost Ratio (OCR), which is defined as follows:

$$OCR = C_d/C_w$$

C_d = Operating and Support Cost of the Alternative Training Technology per unit of Time

C_w = Operating and Support Cost of a Weapon System per unit of Time

The unit of time chosen for the training technology and the weapon system must be identical to that used in the TER. That is, the model takes the time saved on the weapon system in relation to the time spent on the alternative technology and compares it with the relative cost of the two technologies in identical time units. These units can be expressed in minutes, hours, days, even weeks as long as measured uniformly for the TER and OCR. OCR's exceeding a value of one indicate that the technology is more expensive to use in training per unit of time than the weapon system. As such, it would not pay to substitute time on the alternative technology for time on the weapon system. Training on the weapon system would be more cost effective. Where the OCR equals one, no cost savings can be achieved. When the OCR is less than one, however, time on the alternative technology is less expensive per unit of time than that on the weapon system.

Using these measures, cost savings in training a soldier to a specific skill level can be achieved where the TER is greater than the OCR. Where the two measures are equal, or the TER is less than the OCR, no cost savings are achieved through substitution of the alternative training technology for training on the weapon system. In a situation where the TER exceeds the OCR, the value of the time saved in training on the weapon system is greater than the value of the time spent on the training device: The difference between the two represents a cost savings associated with use of the alternative training technology. Table 1 provides an illustration of the relationship between the TER and OCR and their effect on the total cost of

training. As described below, the table also illustrates how the TER and OCR can be used to select the cost minimizing combination of time on the training technology and time on the weapon system.

The information required for this purpose includes the relative cost of training on the weapon system (C_w) and the alternative training technology (C_d) and the results of a transfer effectiveness study where increments of time on the technology are associated with the time saved on the weapon system. The latter permits the determination of the cost minimizing combination of time on the technology and time on the weapon system in training through the calculation of a Marginal Transfer Effectiveness Ratio (MTER).

$$MTER = \Delta(W - W_d)/\Delta(D)$$

The MTER represents the change (Δ) in training time saved on the weapon system for each unit change in time spent on the training technology. As long as the value of the time saved on the weapon system exceeds the value of the additional time spent on the training technology, it will pay in cost saving to spend the additional time on the alternative technology. When the value of the time saved on the weapon system falls below the value of the additional time on the alternative technology, it pays to stop training using the technology and substitute time on the weapon system. The cost minimizing

conditions for use of the alternative training technology are as follows:

$$\mathrm{TER} > 0 \qquad (1)$$

$$\mathrm{OCR} < 1 \qquad (2)$$

$$\text{and} \quad \mathrm{MTER} = \mathrm{OCR} \qquad (3)$$

These cost minimizing conditions are illustrated in Table 1 where we are given C_d = \$1 and C_w = \$10 per hour, along with observations for D and (W - W_d). Both D and (W - W_d) are used to calculate the TER and the MTER associated with each level of usage of the alternative technology. The former are used to produce the OCR. The illustration assumes that training on the weapon system without using the training device (W) requires 40 hours to attain the desired skill level. The column headed by W_d shows the time to criterion on the weapon system when combining time on the weapon system with time on the training device. For example, one hour of time on the device yields a savings in training time on the weapon system of 0.6 hour reducing the time to criterion on the weapon system to 39.4 hours. The cost of one hour on the device is given by C_d*D, \$1. The cost of time on the weapon system after use of the device for one hour is C_w*W_d, \$394. In this example, the total cost of training is reduced from \$400 per hour to \$395 by training one hour on the device.

TABLE 1.1

Simulated Transfer Effectiveness and Cost Data for a Weapon System and Training Device *

D	W_d	$(W-W_d)$	TER	MTER	OCR	C_d*D	C_w*W_d	Total Training Cost w/Device
0	40.0	0.00	-	-	.10	$0	$400	$400
1	39.2	0.80	0.80	-	.10	1	392	393
2	38.6	1.40	.70	.80	.10	2	386	388
3	37.9	2.10	.70	.70	.10	3	379	382
4	37.3	2.70	.67	.60	.10	4	373	377
5	36.7	3.25	.65	.55	.10	5	367	372
6	36.3	3.70	.62	.45	.10	6	363	369
7	35.9	4.10	.59	.40	.10	7	359	366
8	35.5	4.45	.56	.35	.10	8	355	363
9	35.3	4.70	.51	.25	.10	9	353	362
10	35.1	4.90	.49	.20	.10	10	351	361
11	35.0	5.00	.45	.10	.10	11	350	361
12	35.0	5.00	.42	.00	.10	12	350	362
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
50	35.0	5.00	.10	.00	.10	50	350	400

* C_d = $1, C_w = $10

Training on the device for one hour is therefore cost-effective. The total cost of training to the desired skill level is reduced by $5. Two of the three cost minimization conditions are met in this example. The third, setting the MTER equal to the OCR, is not, however. As can be seen in Table 1, spending additional time on the device continues to reduce the time required for training on the weapon system, the value of which exceeds the cost of the additional training on the device. The result is that the total cost of training continues to fall as more time is spent on the training device up to the point where the MTER equals the OCR. Training on the device beyond this point leads to an increase in the total cost of training. Training to the point where the TER equals the OCR results in no cost savings being achieved. The illustration shows that as long as the TER exceeds the OCR, there are cost savings. Maximizing these savings, however, requires equating the MTER and OCR. The above relationships are presented graphically in Figures 1.2(a) and (b).

<u>Reflections on the TER Model</u>

Roscoe's approach integrating training effectiveness and cost measures is focused on cost minimization. The analyst is given a standard of performance for a task and asked to compare alternative training technologies in terms of their cost of achieving this standard. The model does not consider the efficiency of a technology in achieving different standards of performance. To the extent the model does not select performance

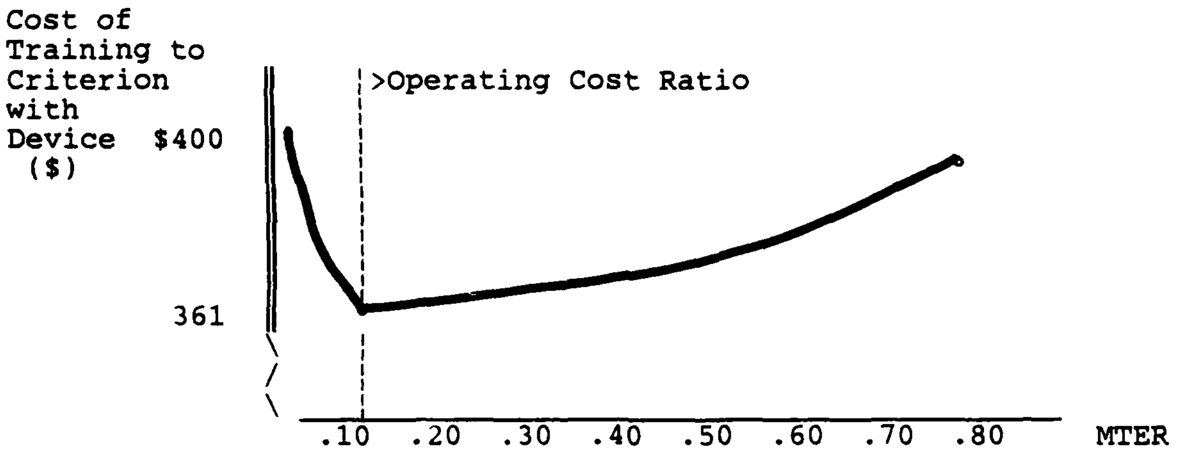

FIGURE 1.2(a) Total Cost of Training to Criterion with Device and Relation to Marginal Transfer Effectiveness Ratio

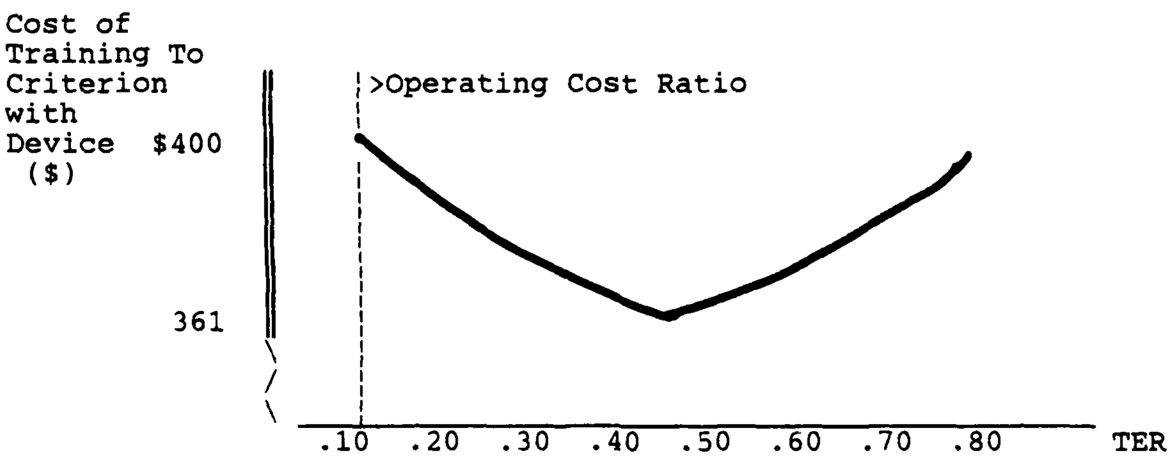

FIGURE 1.2(b) Total Cost of Training to Criterion with Device and Relation to Transfer Effectiveness Ratio

standards where the marginal benefits of the training equal marginal costs, the model is non-optimizing. For those who wish to consider variable effectiveness and variable cost options, the model is of limited utility. It is useful, however, where the standard of performance for a task is given and the issue is determining the most efficient way to train for this task. In this context, the model is well suited to the evaluation of alternative training technologies which can be substituted for training time on a weapon system. The model can also be applied to non-systems training.

Applications of the model, to date, have been limited to aircraft and pilot training where standards of performance are well established. To the extent the policy maker is able and willing to establish these standards, the model can be applied to other weapon systems. Several factors should be kept in mind, however. The model is parsimonious in its data requirements. Nevertheless, data on transfer effectiveness which examine different combinations of time on the alternative training technology and time on the weapon system, may not be readily available. This would certainly be true during the development stage of the system life-cycle. Even comparison-based estimates of this relationship may be difficult to obtain from knowledgable individuals during the development stage. Variations in time on a training device may simply not be feasible to collect, with the result being only one observation or estimate of the TER. As the illustration in Table 1 shows, so long as the TER exceeds the OCR, the model can be used to

determine if an alternative training technology is cost effective. It cannot, however, in this setting, assure that the combination of time using the technology and time on the weapon system will be cost minimizing. The amount of time needed to achieve criterion performance in the baseline technology tends to be regarded as the standard. Nothing could be further from the truth to anyone who has ever considered whether items in a curriculum are "need-to-know" or simply "nice-to-know." In effect, what this means, is that the TER model can be applied to parts of a current curriculum just as meaningfully as to alternative technologies.

Many new technologies for training involve simulators and other training devices along with computer-assisted instruction. The advent of high technology in training makes it possible to train for tasks that cannot be easily undertaken on the weapon system. This introduces a different kind of problem to the evaluation of alternative training technologies. Training for such tasks on a weapon system may be very costly, or in the limit, impossible. Any cost comparison between training on the weapon system and on the device in this situation would be expected to favor the training device. The model, then, is of limited utility where this situation arises. The conclusion is straight forward and it does not require the application of the cost model to determine that the training device is cost effective, although one may nevertheless choose to determine the cost of training for such tasks. The decision in this case rests with whether the benefits of performing these tasks exceed the cost of training for them. The TER model is not concerned with this issue, but with the issue

of how to train to a specific standard of performance. The use of a training technology that can train for these unique tasks, therefore, has to be justified on the basis of whether or not the tasks are worth training for in relation to the cost of the technology.

Determining the cost of training on a weapon system and an alternative training technology requires that the scale of training be specified. This scale refers to the number of trainees required during a training period and to the capacity of the training system. This capacity must consider the flexibility needed to accomodate typical variation in student loads over reasonable periods of time (e.g., within and between years). The scale of training determines, for example, the number of computer stations to be acquired, the size and number of classrooms to be built, and the number of weapons available for training. As a training technology, computer-assisted instruction illustrates the special situation of economies of scale in training. These economies of scale in computer-assisted instruction arise from software development costs, which for some tasks may be quite substantial. These costs become sunk costs once incurred and are unaffected by the scale of training planned. Spreading these costs over large numbers of trainees reduces the cost per trainee. Consequently, where large software development costs are required, the return on investment will vary, increasing with the scale of training planned. This determination cannot be made simply through a comparison of variable costs in the OCR.

Relating these costs to the fixed cost of the training technology requires an extension of the TER model.

Extensions of the Transfer Effectiveness Ratio Model

Roscoe's TER model integrating transfer effectiveness and cost measures can be used to identify a cost minimizing training technology where the output of skills and knowledge, the performance standard, has been predetermined. By using the OCR, the model focuses on savings in operating and support costs, that is, variable costs. In a comparison of any training technology with the alternative of training on the weapon system, so long as the TER exceeds the OCR, the training technology will produce operating and support cost savings in relation to training on the weapon system. However, these savings need to be related to the fixed cost incurred in introducing the new training technology. If the savings are small in relation to the size of capital investment required to introduce the new technology, then other investment alternatives should be considered. The efficient training organization will use its resources to yield the highest return available during the planning period. In the previous example, other training technologies may yield higher rates of return. These technologies and their rate of return, as such, represent an opportunity cost to investment in the new technology.

A simple measure of the rate of return to any training technology during the life a weapon system, defined as the planning period, requires a determination of the stream of cost savings over the period and a comparison of this stream to the

size of the net capital investment required by the technology during the period. The faster this investment is amortized by the stream of cost saving, the higher the return on investment. A training technology that amortizes its fixed cost in two to three years, for example, would have a fairly high rate of return. A more precise measure of this return, however, can be developed which takes into account different time patterns of capital investment and cost savings. This technique, known as cash flow analysis, requires expression of the capital expenditures and cost savings in a time series and the discounting of this series to yield an internal rate of return on investment (IRR). The IRR is the interest rate which equates the present value of the stream of capital expenditures (costs) with the present value of the stream of cost savings (benefits) summed over the planning period is shown below.

$$\Sigma[B_t/(1 + i)^t] - \Sigma[C_t/(1 + i)^t] = 0$$

B_t = Benefits realized in time period t

C_t = Costs incurred in time period t

i = Internal Rate of Return

t = Years in planning period ($t = 1, \ldots., n$)

Where the IRR exceeds the opportunity cost of the capital funds required for investment, the Army, in the interest of efficiency, should adopt the new technology. Where more than one technology is considered in training for a specific task, or set of tasks, the technology which yields the highest IRR should be adopted.

The stream of cost savings associated with using an alternative training technology to reduce the training time on a weapon system can be determined from the components of the TER and OCR. The TER, in its numerator, contains the time in training to criterion on the weapon system without using the alternative training technology, W. The OCR, in its denominator, contains the operating and support cost of the weapon system per unit of time, C_W. The product of the two represents the cost of training a task to criterion on the weapon system without using an alternative training technology.

$$CT = W * C_W$$

CT = Cost of Training to Criterion on Weapon System Without Using an Alternative Training Technology

W = Training Time to Criterion on Weapon System Without Using an Alternative Training Technology

C_W = Operating and Support Cost of Weapon System Per Unit of Time

Where it has been shown that an alternative training technology is cost-effective, i.e. TER > OCR, the total cost savings are determined by subtracting from CT the cost of training to criterion on the weapon system using the alternative training technology. The latter represents the sum of the cost of training to criterion on the weapon system using the alternative training technology and the cost of the alternative training technology. The cost of training to criterion on the weapon system using the alternative training technology is determined as follows:

$$CT_d = W_d * C_w$$

CT_d = Cost of Training to Criterion on the Weapon System Using an Alternative Training Technology

W_d = Time in Training to Criterion on the Weapon System Using an Alternative Training Technology

C_w = Operating and Support Cost of Weapon System per Unit of Time

The cost of the alternative training technology is expressed as follows:

$$CAT = D * C_d$$

CAT = Cost of Training on the Alternative Training Technology

D = Time on the Alternative Training Technology

C_d = Operating and Support Cost of the Alternative Training Technology per Unit of Time

The sum of these costs, CT_d and CAT, gives the total cost of training to criterion combining the weapon system and alternative training technology.

$$CTAT = CT_d + CAT$$

CTAT = Total Cost of Training to Criterion Combining the Weapon System and Alternative Training Technology

Subtracting CTAT from CT yields the total cost savings associated with use of the alternative training technology.

$$CS = CT - CTAT$$

CS = Cost Savings Using the Alternative Training Technology

These cost savings apply to a single task and are attributable to time saved in training on the weapon system. The training, again, involves training to a predetermined skill level. The fact that the TER has already been determined to exceed the OCR assures that the cost savings will be positive, that is, the alternative training technology is cost-effective. The cost savings of the technology for the single task, however, may represent only a fraction of the savings possible since the technology may also be cost-effective in training for other tasks. The total cost savings and stream of benefits attributable to the technology requires summing the savings for each course or task in which the technology is used. To illustrate, suppose in the training of noncommissioned officers as tank commanders, it is determined that computer-assisted instruction as a training technology can be substituted for time on the tank. Furthermore, this substitution is cost-effective for 10 training tasks. This is confirmed by showing that the TER exceeds the OCR in each task. Calculating the total cost savings or benefits associated with use of the technology requires determining the cost savings for each task using the model above and the summation of these savings. This total can then be annualized to represent the stream of benefits per annum to be obtained from using the technology during the planning period. It is this stream of benefits that can be related to the net capital cost of the computer-

assisted instructional system as incurred during the planning period. The time series of benefits in relation to costs provides the basis for calculating the IRR associated with the use of computer-assisted instruction. A similar IRR could be calculated for an alternative technology, SIMCAT, for example, for these tasks and compared with that for computer-assisted instruction. The efficient training organization would choose the training technology yielding the highest IRR.

Several factors can immediately be seen as affecting the IRR for any training technology. One factor involves the extent to which the capital investment required by the technology is fully utilized. If only a few tasks can be trained in a cost-effective manner using the technology and these tasks use only a fraction of the capacity available, the stream of total cost savings is likely to be small in relation to the required capital investment with the result being a low IRR. Even where the capital may be fully utilized, the cost savings may prove to be small in relation to the capital investment resulting in a low IRR. This may follow from the fact that the technology is barely cost-effective yielding very small cost savings, or from the fact that the technology is very expensive to develop and procure. Either could lead to a low IRR. A technology that does not require an expensive capital investment in fixed cost, that is fully utilized, and that yields a sizeable stream of cost savings will produce a high IRR.

This extension of the transfer effectiveness model allows the analyst to go beyond determining if the use of a training

technology is cost-effective in preparing a soldier to perform a specific task to a predetermined standard of performance. It allows the analyst to measure the actual cost savings in training for the task by substituting time using the technology for time on the weapon system. The cost savings can be compared for competing technologies, if available, and related to the size of the capital investment each requires. More importantly, by determining the rate of return to the investment, using the IRR, the analyst is able to apply economic principles to the decision of how to train. If the alternative training technology does not yield a return on investment greater than the opportunity cost of the required investment in fixed cost, it will not pay the Army to use the new technology even though it is shown to be cost-effective. In this situation, the Army can use its resources more efficiently by allocating them to other uses where the return on investment is higher and continuing to train solely on the weapon system.

In the chapter to follow, we illustrate how the model can be used to conduct a CTEA study for computer-assisted instruction on the M1 Tank. The training effectiveness and cost data used are not drawn from actual studies, but are merely illustrations of how the data might look and be used. The chapter assumes that the cost analyst will be given the necessary transfer effectiveness data and must estimate the cost data. This order of events, of course, could be reversed. The components of the OCR are produced, first for the weapon system and then for the training technology. This information can then be combined with

the TER data to determine if the technology is cost-effective. What follows then is an illustration of how the cost savings of the technology during the operations and support phase of the system life-cycle can be determined and related to the fixed cost of development and procurement to estimate a return on the investment. The return is then compared to the assumed opportunity cost and a conclusion reached on whether to train with computer-assisted instruction. The results, again, are not based on actual transfer effectiveness or cost studies and should be considered for illustration purposes only.

CHAPTER TWO

The Development of Cost Data for a CTEA Study of Computer-Assisted Instruction as a Training Technology for the M1 Abrams Tank *

INTRODUCTION

The extended Transfer Effectiveness Ratio model of the preceding chapter presents an economic framework for the integration of cost and training effectiveness data in the decision of how to train. Given a performance standard for each task to be trained, this CTEA model compares the extent to which an alternative training technology can be used to meet this standard at less cost than training directly on a weapon system. The model, as such, focuses on cost minimization in achieving the desired performance standard for the task. The model is well-suited to the selection of training technologies for tasks that are trained on weapon systems whose operation is costly or life threatening. Where expensive training technologies are employed in non-systems training, the model can also be used to evaluate less costly alternative training technologies.

In the event the analyst does not wish to establish a set of performance standards for each task and, instead, wishes to allow both cost and training effectiveness to vary as alternative training technologies and their resource requirements

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* This chapter is prepared by Margaret L. Rayhawk and Arvil V. Adams

are compared, the elements of the model pertaining to cost and training effectiveness will provide the information required for a command decision on how to train. Along with advancements in the measurement of training effectiveness, presented in Volume I of this report, the increased rigor of the cost model and its application of economic cost concepts to the valuation of the resources employed by alternative training technologies promise to improve the quality of information available for decision making in how to optimize training.

In this chapter, we illustrate how the cost data required by the model can be developed and applied with training effectiveness data to the evaluation of computer-assisted instruction as an alternative training technology for the M1 Tank. Training effectiveness data, including transfer effectiveness measures, are discussed in Volume I of this report. The cost data developed are for illustration purposes only and are not products of a validation study prepared for the extended TER model. The objective is to illustrate how the necessary cost data can be developed for a training technology and weapon system. With this objective in mind, the chapter steps the reader through the data development effort applying the economic cost concepts of the previous chapter, developing appropriate cost algorithms, and citing institutional sources of the information needed for a cost study.

Why the M1 Tank?

The extended TER model requires that performance standards for tasks be established. Given these standards, it then proceeds to compare alternative training technologies in terms of their cost of achieving these standards. The focus is on cost minimization in the technology chosen for training. The model is particularly well-suited for tasks that are trained on weapon systems that are expensive to operate or that are life-threatening. The model can be used to compare the cost of training on these systems to that of substituting an alternative training technology. In both cases, the training for a task is to the same standard of performance and only the method of training differs. The question is which is less costly? The M1 tank is costly to use in training. The interest of the Army through its Training Technologies Field Activities (TTFA) unit at Ft. Knox is in finding less costly tank training methods. The model is appropriate for this purpose.

The model, however, need not be restricted to evaluating alternative training technologies for costly training on a weapon system. The model can also be adapted to non-systems training. For example, computer-assisted instruction can be used to train for tasks that are not trained on the M1 Tank. These tasks may instead be trained with another training technology such as miniaturized field exercises. The argument for substituting computer assisted instruction for a miniaturized field exercise would rest on cost minimization. That is, it can train to the same standard of performance as the exercise, but at less cost. Or alternatively, one can raise the standard

of performance and compare the cost of the two technologies in achieving this new standard. To apply the model to non-systems training in this illustration, one would simply substitute the miniaturized field exercise as a training technology for that of training on a weapon system. The comparison would become time to criterion saved in the exercise by substituting computer-assisted instruction. The data requirements of the model applying to the weapon system would now apply to the existing technology of the miniaturized field exercise.

The model is therefore a very versatile analytical framework for choosing how to train. The setting at Ft. Knox includes tasks of both types, those trained on the weapon system and those trained by other means. The illustration in this chapter, however, applies to tasks trained on the M1 Tank and the possible substitution of computer-assisted instruction as a technology for training on the weapon system. The cost elements of both technologies are summarized in Figure 2.1. The important feature of the model is its requirement that a performance standard be specified for each task. As a CTEA model, it differs from other models which allow training effectiveness to vary in conjunction with training costs. The problem with these models, as described in the previous chapter, occurs where training effectiveness is not expressed in terms commensurate with those of cost. As a result, a command decision is required to weigh the value of gains(reductions) in test scores, tanks destroyed, or other measures of training effectiveness when accompanied by increases(decreases) in the cost

Figure 2.1

Summary of Cost Elements for Task Training using the M1 Tank and Computer-Assisted Instruction

TASK TRAINING ON THE M1 TANK

Cost Elements for a Stationary Tank

1. Personnel
2. Petroleum, Oil, and Lubricants
3. Instructional Materials
4. Consumables

Cost Elements for a Moving Tank

1. Personnel
2. Petroleum, Oil, and Lubricants
3. Maintenance and Repair
4. Range Maintenance
5. Instructional Materials
6. Consumables

Cost Elements for a Moving Tank in a Field Exercise

1. Personnel
2. Petroleum, Oil, and Lubricants
3. Maintenance and Repair
4. Range Maintenance
5. Ammunition
6. Instructional Materials
7. Consumables

TASK TRAINING WITH COMPUTER-ASSISTED INSTRUCTION

Cost Elements

1. Personnel
2. Utilities and Maintenance of Facilities
3. System Maintenance

of training. The extended TER model requires that performance standards for training effectiveness be established at the outset and the choice of a training technology revolve around cost minimization in achieving these standards.

Restrictions on Generalizing the Application

The model will be useful for CTEA studies involving a variety of systems and non-systems training including that planned by the TTFA at the U.S. Army Armor Center at Ft. Knox. The illustration of the model in this chapter, including the cost algorithms, involve a specific training technology and weapon system. As a result, the resource elements and data sources will not be transferable to other training settings, but nevertheless should illustrate the general conceptual framework of the model. Elsewhere, Knapp and Orlansky (1983) offer a cost element structure that can be adopted as a check list for identifying training resource elements. The model is also applied to a weapon system that is fully fielded. The application, therefore, does not reflect the conceptual and methodological issues that must be addressed in applying the model to a new weapon system in the early stages of system development.

The analyst should be aware that the existence of sunk costs, which are to be ignored in comparing one training technology with another, depends on the stage of the system life-cycle in which the CTEA study is conducted. Early in the life-cycle one can expect very few sunk costs. Virtually all

resource commitments, including research and development, are yet to be made. Because these resources can still be reprogrammed to other uses at this stage of the system life-cycle, there is a foregone opportunity in their use for developing an alternative training technology. As such, the opportunity cost of these resources must be included in the cost comparison. At later stages of the system life-cycle, however, some resources which cannot be recovered may have been used in training development. A CTEA study at this later stage of the life-cycle must recognize the existence of these sunk costs and exclude them in a cost comparison.

An example of this in the application of the model to the M1 Tank would be the research and development resources employed in fielding the existing training technology for this weapon system. The resources used to develop the existing classroom-based training technology can be ignored in cost comparisons with the alternative of training on the M1 Tank. These resources represent sunk costs in view of the fact that they have been expended and there is very little likelihood, given their unique application, that they can be recovered. Accordingly, they should have no bearing on the decision of whether or not to switch training technologies. The opportunity cost of these resources is reduced to zero. In contrast, however, the resources yet to be used in research and development of an alternative training technology must be included since they do not yet represent sunk costs. Their opportunity cost is greater than zero.

From a methodological perspective, cost estimation promises to be easier for a fielded weapon system and training technology with an experiential data base than for a weapon system in the early stages of development. Determining the operating and support cost of the M1 Tank as a fielded weapon system is a fairly straightforward exercise in view of the existing data base on such costs. The absence of this data base for a new weapon system in the conceptual stages of development makes the task of identifying cost savings for alternative training technologies several degrees more difficult. A methodology for estimating these savings is required. The use of comparison-based predictions offers a promising methodology for this purpose. (Klein Associates, 1985) This approach uses experts to identify fielded systems with characteristics similar to those of the system in development. The existing weapon system and its experiential data base becomes a benchmark for cost and training effectiveness predictions for the new weapon system.

The application of the extended Transfer Effectiveness model to the M1 Tank, focusing on computer-assisted instruction as an alternative training technology, skirts this problem since the weapon system and training technology are well beyond the conceptual stage of the system life-cycle. Data are available on the operating and support costs of each so that comparison-based predictions are not required . Work remains to be done on the development of this methodology for the use of the model at early stages of the weapon system life-cycle. The returns to using the model at this stage of the system life-cycle are likely to be higher than at any later

stage due to the early warning the results can provide on the effects of system design on operating and support costs, including training. System redesigns to achieve reductions in operating and support costs promise to be less expensive at early stages of the system life-cycle than at later stages when expensive retrofitting may be required.

Ground Rules and Assumptions

This chapter illustrates how the elements of the extended Transfer Effectiveness model's Operating Cost Ratio (OCR) can be developed for the training of noncommissioned officers as tank commanders for the M1 Tank. The training involved is for Military Occupational Specialty 19K30 (MOS19K30). The alternative training technology being evaluated is computer-assisted instruction, as found in the Hazeltine Corporation's Time Shared Interactive Computer Controlled Information Television (MicroTICCIT). The training relates to 8 task clusters for MOS19K30, involving 37 sub-tasks, which have been converted into instructional units on MicroTICCIT. This illustration shows how elements of the OCR would be developed for selected sub-tasks for a class of 16 students. Specifically, it explains how to determine the operating and support costs of the M1 Tank per hour of class training time and how to compute the operating and support costs per hour of MicroTICCIT instruction.

The ultimate objective, of course, is to determine for each task the potential for substituting less expensive time on the alternative training technology for more expensive time on

the weapon system while achieving a specified standard of performance and then to determine if the projected cost savings of the alternative training technology for all tasks combined justify the cost of fielding the technology. Resources which are common to both technologies should be factored out of the comparison. A planning period must be selected for the analysis. This illustration uses a 15-year planning period. The planning period will normally correspond with the life-cycle of the weapon system and training technology. That is, it will begin with the research and development of the technology and continue through the procurement and operation and support phases of the system life-cycle. However, if the CTEA study is conducted at a later phase of the life-cycle, say, after the development phase, the planning period will encompass only the procurement and operation and support phases of the life-cycle.

The planning period, representing the expected life of the weapon system, defines the time frame in which benefits in the form of cost savings and costs are measured. It is this time series of benefits and costs that yields the estimated return on investment in the alternative technology. In this illustration, the CTEA study of MicroTICCIT would be conducted near the conclusion of the development phase of this technology's life-cycle. Consequently, the planning period will encompass the procurement and operations and support phases of the technology's life-cycle. Were the study being conducted earlier in the life-cycle, the planning period would include the research and development phase of the life-cycle. With this in mind, the cost incurred in research and development of

MicroTICCIT will be treated in this illustration as a sunk cost. It will not be included in the cost of fielding the alternative training technology because it has been spent and there is little likelihood that these resources can be recovered. As such, economic theory holds that this cost should not be a factor in the decision to adopt the new technology.

The resources that should be included in this decision are those whose opportunity cost is positive. This will include the resources employed in the procurement and operations and support phases of MicroTICCIT's life-cycle. We treat the resources employed in the procurement phase as fixed costs. These resources are necessary to field the new technology. The cost savings expected in the operations and support phase are treated as variable costs. To justify adoption of computer-assisted instruction in the form of MicroTICCIT, the stream of cost savings during the planning period must be large enough to yield a return on the fixed resources that equals or exceeds the opportunity cost of these fixed resources. All costs and cost savings during the planning period will be expressed in constant dollars. Therefore, the appropriate opportunity cost is the time value of money to the Army, which based on historical measures, should be roughly 3 percent.

A Program of Instruction (POI) is available for MOS19K30 which lists the task clusters and sub-tasks to be trained. The POI should be used as a reference in the implementation of the model for cost and training effectiveness data. The POI contains task descriptions and objectives. The model is

applied to each task to determine if the technology is cost effective in training for that task. The analyst should also be familiar with a variety of training documents described below in the sample illustrations. It is also assumed that the analyst will develop a sense of the training organization and the unique features of training at a specific site. The model as applied here refers to school training and does not refer to unit training. We begin the exercise by illustrating how the cost of training per hour on the M1 Tank is constructed and then we proceed to project the cost per hour of MicroTICCIT instruction. Finally, we illustrate how cost savings during the planning period can be related to the fixed cost of fielding MicroTICCIT to determine the Internal Rate of Return to the investment.

HOURLY COST OF TRAINING ON THE WEAPON SYSTEM

Goals and Methods

The goal is to establish the hourly cost of training on the M1 Tank. To understand the nature of the training to be conducted and the resources that will be required, the analyst should begin be reviewing training documents for MOS19K30. The list of documents includes:

1. The program of instruction (POI) for tasks and clusters of tasks to be trained. The POI will also include information on the rank(s) of the expected soldier-trainees for this MOS and the rank(s) of instructors needed for the course.

2. The current course management plan. This should reveal details on the annual number of graduates required to meet mission requirements. It should also include information on the instructor-student ratios expected using different training technologies.

3. The detailed administrative instructions and the ammunition, equipment, and training aids summaries. These will provide details on specific quantities of resources used for training different tasks or groups of tasks in the MOS.

4. The training request forms (TRs) for the most recent run of the course. These forms, provided by the Directorate of Plans, Training, and Mobilization at the Armor Center, describe the resources used in previous training exercises.

A review of these documents should equip the analyst to prepare a training task description for each task to be trained. An example of this description is provided below for the task cluster on military communications and the sub-task of constructing a field expedient antenna. A review of these documents will also show that the cost of training on the weapon system is going to vary with conditions of operation. Specifically, tasks that require a stationary tank will be less costly to train on the weapon system than tasks that require a moving tank, especially where the tank is engaged in actual weapon fire in a full field exercise. Consequently, for illustration purposes, we construct the hourly cost of training on the M1 Tank under three sets of conditions:

stationary, moving, and moving with simulated or actual weapon fire in a full field exercise.

The Stationary Tank

Using the task description in the example below for constructing a field expedient antenna, the cost analyst can identify the relevant operating and support costs for a class of 16 students. The cost elements include personnel, petroleum, oil and lubricants, instructional materials, and consumables.

EXAMPLE ONE

MOS: BNCOC 19K30 M1 Abrams (Tank Commander Training)

TASK CLUSTER ANNEX: Military Communications

SPECIFIC TASK: Construct Field Expedient Antenna

PERIOD OF INSTRUCTION NUMBER: BNCOC C33

OBJECTIVE: Given M1 with broken antenna, field wire, wooden pole, tying and lashing material, and wire cutters for cutting and stripping insulation, student must erect a field expedient antenna and complete a radio check with a monitoring station.

CRITERION: Student must complete within 15 minutes.

CURRENT TRAINING METHODOLOGY: 4 hours of demonstration on a stationery tank by 1 instructor.

STUDENT: E6 and E5 promotables.

INSTRUCTOR(S) E6 or above.

INSTRUCTOR/STUDENT RATIO: 1/16

EQUIPMENT: M1 tank.

STUDENT TO EQUIPMENT RATIO: 16/1

The personnel costs will include pay and allowances for instructors during the time they are engaged in training. Student personnel costs are excluded since they are common to both technologies. If the student time required by training technology is different from that required by the weapon system, then student pay and allowances should be included as a market measure of their value in other production activities which are foregone in order to engage in training, and thus, a measure of their opportunity cost. In addition, dispatching the tank to the training area where it will remain stationary for training requires a tank commander and driver from the active unit. This crew will remain with the tank during the training period and return with the tank to the active unit. The cost of these personnel must also be included in the cost of training for this task.

If the distance from the active unit to the training area is significant, then petroleum, oil, and lubricants costs must be included. Along with these costs, instructional materials, such as field manuals, will be needed by instructors and students. In the consumables category are those items which are expended during training for this task and which are not returned to inventory for use in future training. A

market measure of the cost of these resources is need for conversion into hourly terms to construct a measure of the hourly cost of class training on the M1 Tank while stationery. The exercise is described below.

<u>Personnel Costs:</u> The instructor to student ratio is 1:16. The average instructor is an E6. The tank commander who transports the tank to the training area for the class is an E6 and the driver is an E4. The source for this information includes the POI for the suggested instructor to student ratio and the Directorate of Plans, Training, and Mobilization at the Armor Center for the TR's which will provide information on the rank of the tank commander and driver. The algorithm for determining the hourly personnel cost for training is presented below.

The hourly wage for the E6 instructor is $20.53. The hourly wage cost for this part of the training is calculated as follows:

Number of instructors x instructor hourly wage

Example: 1 X $20.53 = $20.53

The hourly wage for the E6 tank commander is $20.53 and the hourly wage for the E4 driver is $14.31. Their cost is calculated as follows:

Number of tank commanders X hourly wage

\+ Number of drivers X hourly wage.

Example: 1 X $20.53 + 1 X $14.31 = $34.84

TOTAL HOURLY PERSONNEL COSTS: $20.53 + $34.84 = $55.37

Source: "Computation of Benefit Costs for Services of Military Personnel", TRADOC FORSCOM Resource Factor Handbook, Volume 1, Cost Planning Factors, April 1986, p. 10, (revised yearly).

Petroleum, Oil and Lubricant Costs: In this example it is determined that the distance from the active unit to the training area and back is approximately 4 miles. This cost will not vary with the length of time in training once the tank is stationary. Any reduction in training time on the weapon system as a result of using an alternative training technology, short of replacing the weapon system altogether, will not reduce this cost. Consequently, POL cost savings can be ignored.

Instructional Materials: The instructors and students require 17 field manuals for training this task on the weapon system. The cost per manual can be obtained from the Army Publication Center in Baltimore. The analyst will note, however, that the field manuals support many tasks. Unless all tasks are trained exclusively on the new technology, the manuals will still be needed. Accordingly, no cost savings will be achieved in instructional materials. In other examples, task-specific instructional materials may be provided. The analyst will observe that no cost savings will be achieved unless the alternative training technology completely replaces training on the weapon system.

Consumables: The cost of the items consumed in this demonstration, such as field wire and lashing materials, will be small. It is expected that these materials will also be used by the alternative training technology. As such, they represent costs which are common to both technologies and therefore can be factored out of the cost comparison.

Where cost savings can be achieved by reducing time on the weapon system, as in the example of personnel costs, a market-based measure of the opportunity cost of the resource has been used and converted into hourly terms. In this example, we have concluded that the only significant operating and support costs required for training this task on a stationery tank are those involving personnel. The potential cost savings to be achieved in reducing training time on the weapon system are therefore expressed in hourly terms as follows:

Hourly Personnel Costs = \$55.37 = C_W

OPERATING AND SUPPORT COST PER CLASS HOUR FOR TRAINING ON A STATIONARY M1 TANK

The Moving Tank

The task cluster on land navigation and the sub-task of navigating from one point on the ground to another is representative of those tasks that require a moving tank.

The task description is presented below as drawn from the training documents described above. The cost elements for this task include personnel; petroleum,oil and lubricants; maintenance and repairs; range maintenance; instructional materials, and consumables.

The personnel cost will again be based on the pay and allowances of instructors. Note, however, that the instructor to student ratio has changed. Also, more than one tank will be required for the class of 16 students. The number of tank commanders and drivers will be a function of the number of tanks delivered.

EXAMPLE TWO

MOS: BNCOC 19K30 M1 Abrams(Tank Commander Training)

TASK CLUSTER ANNEX: Land Navigation

SPECIFIC TASK: Navigate from One Point on the Ground to Another Point.

PERIOD OF INSTRUCTION NUMBER: BNCOC C20

OBJECTIVE: Given a scaled military map, a compass,an M1, coordinate scale and protractor, a designated start and finish point no more than 5,000 meters apart, the soldier must navigate from start to finish.

CRITERION: Student must complete within 60 minutes.

CURRENT TRAINING METHODOLOGY: .4 hours in classroom with 2.5 hours in tank.

STUDENT: 16 students of E6 or E5 promotables.

INSTRUCTOR(S): E6 or above.

INSTRUCTOR/STUDENT RATIO:1/4.

EQUIPMENT: M1 tank; Lensatic Compass.

STUDENT TO EQUIPMENT RATIO: 4/1

These tanks will each incur costs for petroleum, oil, and lubricants. Maintenance and repairs will be required along with maintenance of the practice range used. Instructional materials, such as field manuals, will be needed by instructors and students. Consumables will include the lensatic compasses found in the equipment summary portion of the POI.

Personnel Costs: The instructor to student ratio is now 1:4 indicating that 4 instructors will be required for a class of 16 students. The average rank of an instructor is an E6. The student to equipment ratio calls for 4 tanks each accompanied by a tank commander and driver from the active unit. The tank commander will be an E6 and the driver an E4. The cost algorithm and sources of information are the same as those used for the stationery tank.

The hourly wage for an E6 instructor is $20.53. The cost for instructors is calculated as:

Number of instructors x instructor hourly wage

Example: 4 X $20.53 = $82.12

The hourly wage for the E6 tank commander is $20.53 and the hourly wage for the E4 driver is $14.31. Their cost is calculated as:

Number of tank commanders x hourly wage +

number of drivers x hourly wage

Example: 4 X $20.53 + 4 X $14.31 = $139.36

TOTAL HOURLY PERSONNEL COSTS: $82.12 + $139.36 = $221.48

<u>Petroleum, Oil and Lubricant Costs:</u> During this exercise, the tanks will be moving and consuming petroleum, oil, and lubricants. The Directorate of Plans, Training, and Mobilization at Ft. Knox will be familiar with the pace of training at the school locale and how the consumption of these products will differ from Army-wide averages. The cost algorithm will reflect the number of tanks, speed, consumption rate, and market cost of these products.

The DPTM tells you that the average speed of the tank during training is 20 miles per hour, that the tank averages 6 gallons a mile, and that the current year (1986) cost per gallon of POL is $0.82. The hourly POL cost for training this task is as follows:

Number of tanks x number of miles per hour
x number of gallons of POL consumed per mile
x price per gallon.

Example: 4 tanks x 20mph x 6gpm x $0.82pg = $393.60

TOTAL HOURLY POL COSTS

Local sources for POL information are generally better to use than sources containing Army-wide averages such as "Petroleum, Oil and Lubricants Costs," price bulletins prepared by the Defense Logistics Agency Administrative Support Center. Local sources reflect local usage and costs.

Maintenance and Repairs: Information on the cost of maintenance and repairs will also be available from the Directorate of Plans, Training, and Mobilization. These costs may be kept by hours of operation or miles traveled. For the latter, the cost algorithm will reflect the number of tanks involved, the number of miles traveled in training, the average maintenance and repair cost per mile, and the number of hours in the training exercise.

If maintenance and repair cost are kept per mile, the hourly maintenance and repair cost will be calculated as follows:

(Number of tanks x number of miles traveled x average maintenance and repair cost per mile) ÷ the number of hours in training exercise

Example: 4 tanks x 30 miles x $45 per mile ÷ 2 1/2 hours of training = $2,160 HOURLY MAINTENANCE AND REPAIR COST

<u>Range Maintenance Costs</u>: After the training exercise on moving tanks is completed, the range where the exercise was conducted will have to be returned to practice readiness. There will be variation in these costs depending on the nature of the training exercise. A simple task such as navigation will require less work than a more complex field exercise involving moving tanks, support vehicles, target engagement, opposing force representation, armored personnel carrier, and other vehicles. For each type of task, the cost of range maintenance can be treated as a function of the hours in use. These costs will rise in proportion to the hours used by the task. Information on range maintenance costs at Ft. Knox can be obtained from the Maintenance Branch of the Range Division of DPTM. The cost algorithm is as follows:

> The hourly rate for <u>simple</u> range maintenance is estimated by the Maintenance Branch to be $30 per hour per tank. The hourly maintenance cost for this task is calculated as:
>
> Number of tanks x hourly range maintenance costs.
>
> Example: 4 x $30 = $120.00 per hour
>
> HOURLY RANGE MAINTENANCE COSTS

<u>Instructional Materials:</u> The field manuals required for this task support many tasks. The cost of the manuals is

excluded since the cost will continue to be incurred unless the alternative training technology replaces the weapon system in training for all related tasks using the manual.

Consumables: Each student will be issued and allowed to keep a lensatic compass and maps for this task. These costs will be incurred regardless of which training technology is used. They are therefore excluded as a potential cost savings.

In each case above where a reduction in training time on the weapon system will release resources to other activities, the model uses a market-based measure of the potential cost savings per hour for training on a moving tank. The potential cost savings for the class in reducing training time on the weapon system where the task requires a moving tank is as follows:

Personnel cost per hour + hourly POL costs + hourly maintenance and repair cost + hourly range maintenance cost = C_W

$221.48 + 393.60 + 2,160.00 + 120.00 = $ 2,895.08

OPERATING AND SUPPORT COST PER CLASS HOUR FOR TRAINING ON MOVING M1 TANKS

The Moving Tank in a Field Exercise

The task cluster identified as tank commander's station/tank gunnery and the sub-task of firing an M250 grenade launcher on an

M1 tank illustrates the cost elements involved in a task requiring a moving tank in a field exercise. The task description is presented below as drawn from the training

EXAMPLE THREE

MOS: BNCOC 19K30 M1 Abrams (Tank Commander Training)

TASK CLUSTER ANNEX: Tank Commander's Station/Tank Gunnery

PERIOD OF INSTRUCTION NAME AND NUMBER: Engage Targets from the Commander's Weapon Station, BNCOC-19K-WPN8.

SUBTASK: Perform Grenade Launcher Firing Procedures, Task Number 171-126-1028.

OBJECTIVE: Given an M1 tank with crew, loaded M250 grenade launcher, the commander's station powered up, student will perform grenade launcher firing procedures, (actual firing simulated), failure to fire procedures,and grenade failure to burst or burn procedures.

CRITERION: Student must complete within 3 minutes.

CURRENT TRAINING METHODOLOGY: In addition to demonstration training and classroom/lecture time, training this task represents 6 hours of a 72-hour Situational Training Exercise (STX).

STUDENT: E6 and E5 promotables.

INSTRUCTORS, SUPPORT PERSONNEL, WEAPON AND TRANSPORT VEHICLES, ARMS AND AMMUNITION (Live and Inert), ANTI-PERSONNEL MINES, TRAINING DEVICES, AND MISCELLANEOUS EQUIPMENT: Numbers and Ratios will vary.

documents described earlier. These are costly tasks to train on the weapon system, and therefore, likely to generate cost savings when training with an alternative training technology. The training for these tasks involves a situational training exercise with troops, support equipment, and personnel in the field for several days running. A variety of tasks are trained during the field exercise. These tasks share the operating and support cost of the training exercise. Accordingly, with the exception of personnel costs, we plan to determine the cost per class hour for training this task by calculating the cost of the situational training exercise for each cost element and dividing by the number of hours in the training exercise. The effect of this is to make the hourly cost of training each task the same, although the total cost for each task will depend on the number of hours it requires during the training exercise. The cost elements for the task include: personnel; petroleum, oil, and lubricants; maintenance and repairs; range maintenance; ammunition; instructional materials, and consumables.

Personnel Costs: In addition to the instructors, tank commanders, and tank drivers, an extended network of support personnel will be required. A sample data collection sheet is presented below with a list of these personnel. The list shows for each occupational specialty the number of personnel required, the average grade, the hourly pay scale, and the total hourly cost. Summing the total hourly cost by occupational specialty gives the hourly personnel cost required by the situational training exercise. DPTM and its Training Requests (TR's) would

Sample Date Collection Sheet
Hourly Personnel Cost

PERSONNEL	NUMBER	AVERAGE GRADE	HOURLY PAY SCALE	NUMBER x HOURLY PAY SCALE EQUALS STX HOURLY PERSONNEL COSTS
Instructors	4	E6	.	.
Transport Tank Commanders	4	E6	.	.
Transport Tank Drivers	4	E6	.	.
<u>Drivers:</u>				
Armored Personnel Carriers	3	E4	.	.
2 1/2 Ton Truck	1	E3	.	.
Ambulance	1	E3	.	.
Water Trailer	1	E3	.	.
1/4 Ton Truck	1	E3	.	.
5 Ton Wrecker	1	E3	.	.
<u>Field Staff</u>:				
Target Placement	10	E4	.	.
Food Preparation	8	E2	.	.
Medical Corps	8	___[1]	.	.
Equipment Management	8	E3	.	.
<u>Other</u>:				
Include all other	.	.	.	.
		TOTAL STX HOURLY PERSONNEL COSTS:		$1,350

---

[1] Possible mix of officer and enlisted personnel.

again be the source for determining the personnel requirements for this exercise. Pay and allowances for each grade would be found in the TRADOC FORSCOM Resource Factor Handbook, Vol. I.

Completion of the data collection sheet would yield hourly personnel cost for the situational training exercise.

STX hourly personnel costs = Sum of categorical costs
STX HOURLY PERSONNEL COSTS = $1,350

Petroleum, Oil and Lubricant Costs: A list of vehicles to be used in the situational training exercise is presented below. The list is used to collect information on usage, miles traveled, gallons consumed per mile for each type of vehicle, POL cost per gallon, and the number of vehicles of each type. DPTM supply personnel are a source for this information as are unit personnel supplying the vehicles. The training requests available from DPTM provide information on the projected usage of each vehicle. Some vehicles will be used merely for transportation to the field and back. Others, however, such as the wrecker and armored personnel carriers will possibly be used throughout the exercise.

The situational training exercise in this example is projected to last 6 days and include 72 training hours. Once the list of vehicles has been prepared and the required information obtained,

Data Collection Sheet

STX POL Cost Components and Estimates for Other Support Vehicles

VEHICLE	USAGE	(1) MILES	(2) GAL/ MILE	(3) COST PER GALLON	(4) NUMBER OF VEHICLES	POL COSTS [1 x 2 x 3 x 4]
Armored Personnel Carrier	One Round Trip	16	8	$0.93	3	$ 357.12
2 1/2 Ton Truck	One Round Trip	16	.	.	1	.
Ambulance	One Round Trip	16	.	.	1	.
Water Trailer	One Round Trip	16	.	.	1	.
M1 Tank	30/mi day / 6 days	180	.	.	4	.
1/4 Ton Truck	Three Round Trips	48	.	.	1	.
Five Ton Wrecker	One Round Trip	16	.	.	1	.
			TOTAL STX POL COST			$5,650.00

the POL cost for each type of vehicle can be determined. The POL cost can then be summed for each type of vehicle to produce the total POL cost of tanks and support vehicles for the situational training exercise. This cost is then divided by the number of training hours in the exercise as follows:

Total STX POL cost ÷ hours in the STX
Example: $5,650 ÷ 72 = $ 78.47
STX HOURLY POL COST

Maintenance and Repairs: DPTM will again be the source for information on the cost of vehicle maintenance and repairs. As mentioned above, records may be kept several ways and the cost algorithm will have to be adjusted accordingly. Maintenance and repair costs may be kept for each vehicle by hours of operation or miles traveled. Other ways may include annual cost per vehicle, cost per day in the field, or even as a factor of another cost such as a percentage of the vehicle cost. In this example, we develop the algorithm based on maintenance and repair costs being kept by miles traveled. The cost algorithm will reflect for each type of vehicle, the number of vehicles involved, the number of miles traveled in the training exercise, the average maintenance and repair cost per mile, and the number of hours in the situational training exercise. Any reduction in training time is considered to

For maintenance and repair cost kept per mile, the total maintenance and repair cost will be calculated for each type of vehicle as follows:

Number of vehicles x number of miles traveled x average maintenance and repair cost per mile

Example for tanks: 4 x 180 x $45 = $32,400

The total hourly maintenance and repair cost will be the sum of the total maintenance and repair cost for all vehicles divided by the number of training hours in the STX

Example: Assuming the total maintenance and repair cost is $36,500

$36,500 ÷ 72 = $506.94

STX HOURLY MAINTENANCE AND REPAIR COST

reduce proportionately the distance traveled, and therefore, the cost of maintenance and repairs.

Range Maintenance Costs: Due to the number of vehicles and the level of activity involved in a situational training exercise, the cost of restoring the range to practice readiness is expected to be higher than that of a simple field exercise. The Maintenance Branch

of the Range Division of DPTM at Ft. Knox will be the source of information on these costs. Records may be kept on the basis of hours in the field or by type of situational training exercise. The cost algorithm will be adjusted accordingly. The algorithm will treat the cost of range maintenance as a function of hours in use. The cost of range maintenance will rise proportionately with the hours in use.

> The cost of range maintenance for a situational field exercise is estimated to be \$600 per day per tank. The hourly range maintenance cost is calculated as follows:
>
> (Number of days in STX x daily range maintenance cost per tank for STX x number of tanks) ÷ hours in STX
>
> Example: (6 x \$600 x 4) ÷ 72 = \$200
>
> STX HOURLY RANGE MAINTENANCE COST

Ammunition: The ammunition summary of the POI will provide a list of the ammunition to be consumed in the situational training exercise. A data collection sheet for the cost algorithm is provided below requiring information on the number of rounds needed for each type of ammunition and the cost per round. This information can be drawn from the Supplies and Services Division of the Directorate for Logistics. DPTM can also assist the cost analyst in obtaining this information. The summary lists separately the rounds of ammunition required by students and those used to simulate battle conditions. Only those items to be used in the

Data Collection Sheet
CONSUMABLES: AMMUNITION

ITEM DESCRIPTION	(1) QUANTITY PER STUDENT	(2) NO.OF STUD.	STUDENT NEEDS [1 x 2]	QUANTITY OF OTHER ROUNDS	(3) TOTAL NEED	(4) PER ITEM COST	TOTAL COST 3 X 4
Ctg,7.62mm Blank Linked	250	16	4,000	____	4,000	$___	$_____
Ctg, Cal .50 Blank, M1A1 w/M9 Link	150	16	2,400	____	2,400	___	_____
Gren, Hand Smoke, Green	___	___	____	112	112	___	_____
Gren, Hand Smoke, Yellow	___	___	____	92	92	___	_____
Gren, Hand CS, M7 Series	___	___	____	16	16	___	_____
Gren, Hand Smoke Red	___	___	____	84	84	___	_____
Sig, Gnd Star Para White	___	___	____	48	48	___	_____
Sig, Gnd,Green Star Cluster	___	___	____	48	48	___	_____
Simulator Projectile Ground Burst M115A2	___	___	____	150	150	___	_____
Simulator Flash Art M21	___	___	____	720	720	___	_____
Simulator Atomic Explosion M192 XM14251	___	___	____	2	2	___	_____

TOTAL EXPENDED AMMUNITION COST $25,000

exercise are included on the list. It may be possible to identify the actual ammunition used in training for a task and its cost, but in other situations, munitions may be used to simulate an opposition force, compounding the accounting problem. As an alternative, we elect here simply to distribute the total ammunition cost uniformly over the training exercise as follows:

Sum of ammunition costs ÷ hours in situational training exercise.
$25,000 ÷ 72 = $347.22
STX HOURLY EXPENDED AMMUNITION COSTS

Instructional Materials: As in the example for the moving tank above, instructional materials will still be needed unless the alternative training technology completely replaces training on the weapon system. Resources common to both training technologies--training on the weapon system and computer-assisted instruction--can be excluded in the cost comparison.

Consumables: Consumables, other than ammunition which is treated separately above, are not expected to vary with the training technology used, and like the instructional materials above, are excluded in the cost comparison.

For each cost element above, the cost analyst is expected to use a market-based measure of the opportunity cost of the resources used in training on a moving tank in a field exercise. The potential cost savings to be achieved for the class in reducing training time

on the weapon system where the task requires a moving tank in a situational training exercise is expressed as follows:

Hourly personnel costs + hourly POL cost + hourly maintenance and repair cost + hourly range maintenance cost + hourly ammunition cost = C_w

Example: $1,350 + 78 + 507 + 200 + 347 = $2,482

OPERATING AND SUPPORT COST PER CLASS HOUR FOR TRAINING ON MOVING M1 TANKS IN A SITUATIONAL TRAINING EXERCISE

The preceding cost analyses have estimated the operating and support cost of the weapon system per hour (C_w) as required for the Operating Cost Ratio. We have elected to estimate C_w under three sets of conditions for the M1 Tank: stationery, moving, and moving in a field exercise.

Weapon Status	C_w
Stationary	$ 55
Moving	2,895
Moving in STX	2,482

Each weapon status yields a different operating and support cost linked to the opportunity cost of the resources used. The cost per class hour for training on a moving tank in a situational training

exercise is slightly less than that when not involved in a situational training exercise. The difference is explained by the intensity of distance traveled per hour by the weapon system in each case. This measure is an important cost factor in the model. With less distance traveled per hour by the weapon system in the situational training exercise, its operating and support cost per hour is reduced. For tasks that require one or another of these three conditions, these estimates provide a better measure of the potential cost savings associated with reducing training time on the weapon system. Naturally, the potential cost savings are larger for those tasks that involve the tank in motion. We now proceed to calculate the operating and support cost of the alternative training technology (C_d) to complete the information needed for the OCR.

HOURLY COST OF COMPUTER-ASSISTED INSTRUCTION WITH MicroTICCIT

Goals and Methods

The goal is to establish the hourly cost of training on MicroTICCIT for MOS19K30. The training involves 8 task clusters and 37 sub-tasks which have been converted into instructional units on MicroTICCIT. A list of these sub-tasks is presented below. The list includes task clusters such as "Nuclear, Biological, and Chemical Warfare and Communications Electronics Operating Instructions," which are not specific to MOS19K30. The courseware can therefore be used for training in other MOS's requiring the soldier to perform these tasks. This will become important as we move later to relate the potential cost savings of computer-assisted instruction to the fixed cost of fielding the new technology.

Instructional Units Programmed on MicroTICCIT by Task Cluster and Sub-Task

Communications Electronics Operating Instructions
- Item Identifiers
- Call Signs
- Suffixes
- Frequencies
- Encoding
- Decoding
- Authentication
- Radio Procedures

Land Navigation
- Determine Grid Coordinates
- Analyze Terrain Using Five Aspects of Terrain
- Identify Natural Terrain Features
- Determine Elevation
- Orient Map to Ground by Terrain Association
- Determine Location by Terrain Association
- Locate an Unknown Point by Intersection and Resection

Land Navigation Using Surrogate Travel
- Determine Location by Terrain Association
- Navigate from One Point on the Ground to Another
- Reconnaissance by Surrogate Travel

Fire Commands
- Stationary Tank, Stationary Target
- Stationary Tank, Moving Target
- Stationary Tank, Multiple Targets
- Simultaneous Engagements

Remediation
- Determine Grid Coordinates
- Communciate Using Visual Signaling Techniques
- Recognize and Identify Friendly and Threat Vehicles
- Establish Tank Firing Positions

Nuclear, Biological, and Chemical Warfare
- NBC Reporting
- Radiacmeter
- Dosimeter
- Chemical Kit

Mine Warfare
- Install a Hasty Protective Minefield
- Direct a Minefield Marking Party

Call For/Adjust Indirect Fire
- Range Estimation
- "Mil" Formula
- Grid Missions
- Shift from a Known Point
- Polar Plot

The focus is on the operating and support cost of the new technology. Like other forms of computer-assisted instruction, the fixed cost of fielding the technology in special facilities, hardware, courseware, and instructional materials is quite significant, but once in place, the operating and support cost is fairly low with cost elements including personnel, utilities and maintenance of facilities, and system maintenance. To determine the resources required for use of MicroTICCIT, the cost analyst will need to consult with the TTFA at Ft. Knox. which has been responsible for the development of the alternative training technology.

<u>Personnel Costs</u>

An instructor will direct class activities in MicroTICCIT in a computer laboratory setting with trainees working at individual stations for fixed periods of time. The instructor-student ratio will be 1:16 with the instructor expected to be an E6. The opportunity cost of trainee time, as described above for training on the weapon system, will be incurred under both technologies and can be excluded in considering the additional costs associated with this technology. The cost algorithm for personnel is expressed as follows:

The hourly wage for the E6 instructor is \$20.53.
Number of instructors x instructor hourly wage
Example: 1 x \$20.53 = \$20.53

HOURLY PERSONNEL COSTS: $20.53

Source: "Computation of Benefit Costs for Services of Military Personnel", TRADOC FORSCOM Resource Factor Handbook, Volume 1, Cost Planning Factors, April 1986, p.10, (revised yearly).

Utilities and Maintenance of Facilities

MicroTICCIT will be situated in a climate controlled environment. The sensitivity of computers to humidity and air pollution requires this. The modification of classroom facilities to provide this environment will be an added cost of fielding the new technology. The nature of the environmental controls for computer-assisted instruction exceeds that for other training technologies and therefore represents a cost that must be recovered in cost savings to justify use of the technology. Determining the cost of these controls will require consultation with the TTFA and with the Directorate of Engineering and Housing at Ft. Knox. The cost of operating and supporting these controls will include utilities and maintenance. The computers will also require additional electrical circuitry and with this will come the operating and support cost of additional utilities. The Directorate of Engineering and Housing through its Utilities and Structure Division, together with the TTFA, will be the source of information on both the procurement cost of the additional facilities and the operating and support cost of these facilties. The latter may be reported on an annual, monthly, or even weekly basis and the cost algorithm will have to be adjusted accordingly to reflect

the cost per training hour, assuming a 40 hour training week. The algorithm will include:

Utilities \$/hour + maintenance of facilities \$/hr
Example: \$2.00 + 1.25 = \$3.25 per class hour
UTILITIES AND MAINTENANCE OF FACILITIES COST PER CLASS HOUR

<u>System Maintenance</u>

Once MicroTICCIT is in place, the system will have to be maintained. The cost of this will normally be handled in one of two ways. The Army will either pay for a system maintenance contract on an annual or multi-year basis, or it will pay for services rendered when needed. A service contract may be purchased with the system and treated as a fixed cost; however, it is more likely that such a contract will be entered into following procurement and treated as an annual operating and support cost. The source of information for system maintenance cost should be the vendor, Hazeltine. The algorithm for this cost will most likely include system cost, type of components, and vintage of the system. The cost analyst should rely on the vendor for this information with annual costs adjusted to hourly terms assuming a training-year to include 2,080 hours. Training-years may differ from school to school, e.g. open on Saturdays, reduced hours for holidays, and therefore, the cost analyst should use the local relevant number rather than 2,080 hours. For this example, we use

$8,000 as the annual cost of a system maintenance contract and adjust it as follows:

> Annual system maintenance cost ÷ 2080 hrs.
>
> Example: $8,000 ÷ 2080 = $3.85
>
> HOURLY SYSTEM MAINTENANCE COST

In each example above, the cost analyst is expected to use market-based prices for the resources required by the alternative training technology to determine the operating and support cost per class hour for training a task. The approach taken assumes that the hourly cost of training one task on MicroTICCIT will be the same as for training another task. The total cost for training a task, of course, will vary with the number of hours the task requires on the system. The approach also assumes that the system is fully utilized. Where a cost element is adjusted to hourly terms, spreading the cost over fewer hours would increase the hourly cost of training and reduce the potential cost savings for any one task. The hourly cost of the alternative training technology is expressed as follows:

> Hourly personnel costs + hourly utilities and facilities maintenance cost + hourly system maintenance cost = C_d
>
> Example: $20.53 + 3.25 + 3.85 = $27.53

OPERATING AND SUPPORT COST PER CLASS HOUR FOR TRAINING ON MicroTICCIT

THE INTEGRATION OF COST AND TRAINING EFFECTIVENESS DATA

At this point in the exercise we have developed the necessary cost data for conducting a CTEA study of MicroTICCIT as an alternative training technology to training on the M1 Tank. The training to which this technology applies covers 8 task clusters and 37 sub-tasks for MOS19K30. The data developed, C_d and C_w, represent the elements of the Operating Cost Ratio required by the extended Transfer Effectiveness model described in the previous chapter. Implementation of the model requires that we obtain, in addition, the elements of the Transfer Effectiveness Ratio, $(W - W_d)$ and D. These elements will be drawn from a transfer effectiveness study which for each task determines the time saved in training to a specified performance standard on the weapon system by substituting time on the alternative training technology. Ideally, not only will we obtain for each task a TER, but a series of TER's showing the relationship between time saved on the weapon system and time spent on the technology. This will permit us to construct Marginal Training Effectiveness Ratios which the model shows can be used to identify the cost minimizing amount of time to spend on the alternative training technology.

The model shows, however, that if the MTER ratios cannot be obtained, a single TER for each task can be used to determine if the alternative training technology is cost-effective in training

the task to a specified performance standard. In this example, we will assume we are given a single TER for each of the 3 tasks for which weapon system cost data have been developed. The TER's are as follows:

TASK	$TER = (W - W_d)/D$
1. Construct a field expedient antenna	$0.50 = (4.0 - 3.0)/2.0$
2. Navigate from one point on the ground to another	$0.67 = (2.5 - 1.5)/1.5$
3. Perform grenade launcher procedures	$1.00 = (6.0 - 5.0)/1.0$

Is MicroTICCIT Cost-Effective?

To determine if MicroTICCIT is cost-effective, the model requires that 3 conditions be satisfied. The TER must be positive implying that some positive amount of time in training on the weapon system can be saved by using the alternative training technology. The OCR must be less than one, meaning that the cost per hour of training on the alternative training technology is less than that on the weapon. And finally, the TER must exceed the OCR indicating that the value of the time saved on the weapon system more than exceeds the cost of the time on the alternative training technology resulting in net cost savings.

$$TER > 0 \qquad (1)$$

$$OCR < 1 \qquad (2)$$

$$\text{and} \quad TER > OCR \qquad (3)$$

The first of these conditions is satisfied as shown above. The second is also satisfied as shown below:

TASK	$OCR = C_d/C_w$
1. Construct a field expedient antenna	0.51 = 28/55
2. Navigate from one point on the ground to another	0.01 = 28/2,895
3. Perform grenade launcher procedures	0.01 = 28/2,482

The third condition, however, is satisfied only for tasks 2 and 3. In the case of task 1, the value of the time saved in training on the M1 Tank is less than the cost of the time spent training on MicroTiccit. The result for task 1 is that it is cheaper to train for this task on the weapon system than on MicroTICCIT. The opposite is true, however, for tasks 2 and 3. Using MicroTICCIT to train to the desired performance standard for these tasks will result in substantial cost savings based on the data presented in these examples. The reader should be reminded, of course, that these data are not derived from a validation study and are merely for illustrative purposes only. Using these data, it is possible to determine the actual cost savings for tasks 2 and 3.

Measuring the Cost Savings

The model's cost savings equation in the preceding chapter can be expressed as follows:

$$CS = W*C_w - [W_d*C_w + D*C_d]$$

where,

CS = Cost savings using the alternative training technology

W = Time in training to criterion on weapon system without using an alternative training technology

C_w = Operating and support cost per class hour of weapon system

W_d = Time in training to criterion on weapon system with an alternative training technology

D = Time on the alternative training technology

C_d = Operating and support cost per class hour of alternative training technology

Substituting the data available for task 2, we find the following cost savings:

$$CS = 2.5 * \$2,895 - [(1.5 * \$2,895) + (1.5 * \$28)]$$

$$= \$7,237.50 - \$4384.50$$

$$= \$2,853$$

For task 3, the cost savings are expected to be:

$$CS = 6.0 * \$2,482 - [(5.0 * \$2,482) + (1 * \$28)]$$

$$= \$14,892 - \$12,438$$

$$= \$2,454$$

Based on the cost and training effectiveness data presented here, the cost savings associated with training task 2 on MicroTICCIT are estimated to be $2,853. The alternative training technology is successful in reducing the cost of training for this task from $7,235.50 to $4,384.50. The 1.5 hours spent on MicroTICCIT, costing $42, replaced 1 hour on a moving M1 Tank valued at $2,895. Both technologies trained the task to the same standard of performance. For task 3, the cost savings were $2,454.

To determine the total cost savings achieved with MicroTICCIT for MOS19K30, the model's parameters must be estimated for each of the 37 sub-tasks. For tasks satisfying all 3 conditions of the model, indicating that the alternative training technology is cost effective, the cost savings can be determined as shown above. The sum of these savings for the tasks for which MicroTICCIT is found to be cost-effective yields the total cost savings to be obtained from the technology's use with one class of trainees.

For the purpose of this illustration, we assume that the total cost savings obtained with MicroTICCIT for one class of MOS19K30

trainees is $15,000. Each class lasts 6 weeks with 8 classes conducted during the calendar year. With 8 classes conducted per annum, the annual savings for MOS19K30 would be $120,000. As suggested earlier, if the number of hours spent by a class on MicroTICCIT is less than the 40 hours available each week, as most certainly will be the case, the operating and support cost of the system in utilities, maintenance of facilities, and systems maintenance will have to be spread over the number of hours actually used. This will reduce the cost savings, but not significantly since these costs are relatively small.

If another MOS shares use of the system along with MOS19K30, then these costs can be apportioned between the 2 MOS's. The extrapolation of the annualized cost savings to other years in the planning period produces the stream of benefits to be associated with the cost of fielding MicroTICCIT. In constant dollars, the stream represents $120,000 in benefits per annum during the 15 year planning period. Is this stream sufficiently large to pay for the cost of fielding the new technology and also produce a positive return on the investment? Will this return exceed the opportunity cost of the funds invested? Our extension of the Transfer Effectiveness model applies the methods of cash flow analysis to answer these questions.

CONSTRUCTING THE RETURN ON INVESTMENT

The application of cash flow analysis to these questions requires that the benefits and costs of using MicroTICCIT be determined for the planning period in the time sequence in which

they will occur. The benefits in the form of cost savings are determined above as $120,000 each year of the planning period once the technology is fielded. This, of course, assumes that training for MOS19K30 will continue at the same level throughout the planning period. The benefits are expressed in constant dollars. The cost of fielding MicroTICCIT provides the necessary stream of costs for comparison with the benefits of the technology. These costs should also be expressed in constant dollars. Since benefits and costs are realized at different points in time, it is necessary to adjust them for the time value of money using present value analysis. Once done, comparisons can be made and the questions above addressed.

Measuring Investment Costs

The first step in this exercise is the determination of the cost of fielding MicroTICCIT. We expect the benefits to exceed this cost and provide a return on the investment that at least equals the best alternative use for these funds. From a life-cycle perspective, the cost of fielding a training technology includes development and procurement costs. However, where one stands in the life-cycle when conducting the CTEA study can influence the treatment of these costs. In this example, the development cost for MicroTICCIT have already been incurred and the system is approaching the procurement stage of the life-cycle. Most of these development costs can be treated as sunk costs and excluded from the analysis on the premise that they cannot be recaptured at this point and converted to other uses. Their opportunity cost, in other words, is zero.

Courseware development, however, has created a product which extends to training beyond MOS19K30, and which therefore offers a means for recapturing the resources employed in this development. The more general the courseware developed, the more likely it will have a market value, and therefore, a positive opportunity cost. Highly specific courseware, however, is less likely to offer alternative uses. In the current application, the development cost of this courseware would be treated as a sunk cost and excluded from the cost of investment. If the CTEA study were being conducted at the outset of the development phase of the life-cycle, then all development costs would be included in the cost of fielding the technology. The key here is the opportunity cost of the resources employed. Resources with a positive opportunity cost should be included in the analysis.

Treating courseware development as part of the cost of fielding MicroTICCIT creates a special problem. Since the courseware can be used for other MOS training, requiring MOS19K30 to pay for this development stacks the deck against the investment generating a positive return, especially when the cost of courseware development is substantial. The problem could be addressed in one of two ways. The first would require that the cost savings created by the courseware for other MOS's be included in the stream of benefits to be weighed against the cost of the investment. The evaluation would shift in this example from the cost-effectiveness of the courseware and MicroTICCIT for MOS19K30 to a cost-effectiveness study for the courseware and technology that is not MOS specific. The second would attempt to apportion

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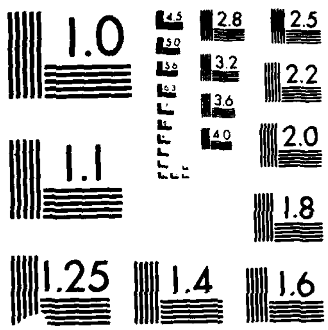

UTION TEST CHART

the courseware development cost among the MOS's in which it can be used with MOS19K30 assuming its share.

There is a second dimension to this problem for computer-assisted instruction that would apply even to highly specific courseware which might be used for only one MOS. This dimension applies to the scale of training offered. Courseware development is a one-time cost which is independent of the scale of training. The cost of reproducing the courseware once developed is negligible such that the development cost of the courseware will remain virtually unchanged whether used with 100 or 1,000 trainees a year. In this example, we have a fairly small number of trainees, approximately 100 a year and we are asking this small number to generate enough cost savings to pay for the courseware development. This also stacks the deck against the investment. The implication of this is that highly specific courseware developed for small volume training will be much more difficult to justify than for large volume training in terms of its return on investment.

With this caveat in mind, we move to measuring the cost of fielding MicroTICCIT. The cost elements included from the development and procurement phases of the life-cycle are: courseware development, hardware, software, instructional materials, and facilities.

Courseware Development: Orlansky (1985) refers to courseware development as one of the more difficult cost elements to estimate. There is no generally accepted algorithm for arriving at this cost. A crude method calls for determining the number of hours of instruction to be developed and then multiplying this by an average cost for courseware development per hour of instruction.

In our example, 50 hours of instruction have been developed covering the 37 sub-tasks. The TTFA estimates that the average cost per hour of instruction for courseware is $12,000, or a total courseware development cost of $600,000. Over time courseware requires revision to update training doctrines. The revision of the courseware will add additional cost to the investment to be recovered in cost savings. The analyst will have to determine how frequently the revisions will occur and the cost of each revision. In this illustration, we assume revisions every 5 years at the same cost per hour as the initial courseware development.

To demonstrate the impact of forcing a small scale training exercise for a single MOS to pay back the cost of fielding the technology, we develop two cost streams. The first will assign all courseware development cost to MOS19K30. The second will assign only half of the cost to this MOS. The remainder would be assigned to other MOS training using the courseware and technology. The two cost streams over the 15-year planning period appear as follows:

Period	Full Cost	Half Cost
1	($600,000)	($300,000)
2	0	0
3	0	0
4	0	0
5	0	0
6	(600,000)	(300,000)
7	0	0
8	0	0
9	0	0
10	0	0
11	(600,000)	(300,000)
12	0	0
13	0	0
14	0	0
15	0	0

Hardware and Software: MicroTICCIT is sold by Hazeltine as an integrated system of hardware and software. The system includes a Data General host station, an instructor's workstation, and trainee workstations. The equipment-trainee ratio is one to one. The hardware requirements are listed below. For the class of 16 trainees, one host station will be required, one instructor's station, and 16 trainee workstations. The initial cost of this hardware, bundled with the necessary software to use the courseware, can be obtained from the vendor and the TTFA. For illustration, we use $25,000 for the host station and software, $7,000 for the instructor's station, and $6,000 for each trainee workstation, yielding a total hardware and software cost of $128,000.

The cost analyst will also have to determine the expected life of the system. We use an expected life of 8 years after which the system will have to be replaced. At the conclusion of the planning period, the replaced equipment may have some residual value. If so, this value will be subtracted from the cost of the hardware. The residual value should reflect the opportunity cost of the resource in the final period. If a used computer market exists, the price set in this market is the best measure of the residual value and the opportunity cost of the resource. In this example, we set the residual value of the MicroTICCIT system at 10 percent of its initial cost. The cost stream for hardware and software appears as follows:

Period	Cost
1	($128,000)
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	(128,000)
10	0
11	0
12	0
13	0
14	0
15	12,800

Instructional Materials: Manuals containing technical information about MicroTICCIT and its maintenance will be required along with an instructor's guide for each instructional unit. These materials, like the software, may be bundled with the hardware. However, they may also be sold separately and should be accounted for as part of the cost of fielding the system. Moreover, they will have to be replaced at the time the hardware and software are replaced. The TTFA and the vendor, Hazeltine, can be consulted for this information. In this example, we treat these items as having been bundled with the hardware and software. We therefore introduce no separate cost for this item.

Facilities: Classroom space will be required for MicroTICCIT and, as we suggested above, special environmental controls will also be needed. The cost of the environmental controls can be determined by consulting with the Utilities and Structure Division of the Directorate of Engineering and Housing at Ft. Knox and the TTFA. The cost of the basic facilities, apart from these controls, is

more difficult to determine. The facilities may already exist and simply have to be requisitioned for use by MicroTICCIT. The question is what is the opportunity cost of these facilities? It may be determined that the space would be idle in the absence of its use for MicroTICCIT. If so, its opportunity cost can be treated as zero and only the cost of the environmental controls added to the cost stream.

However, it is more likely the space will have alternative uses, and it can be assumed that the value of the space, in terms of these foregone uses, is positive. In this case, the task is to determine what this opportunity cost is. In a market economy, the rental cost per square foot for this space or similar space should be used as a measure of the opportunity cost. On the post, however, this measure is not available. The analyst must use his or her judgment in setting the value of the space. If the space has been recently constructed, the analyst might capitalize the cost of construction to arrive at a market lease cost per square foot. Alternatively, the analyst may observe market rents for similar space off post, if available, and price the space accordingly.

For this illustration, we use a value of $8.50 per square foot and initial leasehold improvements for environmental controls of $25,000. We allow 60 square feet per workstation plus an additional 120 square feet for the host station and instructor's workstation. The total space requirement is 1,080 square feet with an annual rental value of $9,180. We further assume that at the end of the 15 year planning period, the residual value of the leasehold

improvements is zero. The cost stream associated with these facilities is as follows:

Period	Cost
1	($34,180)
2	(9,180)
3	(9,180)
4	(9,180)
5	(9,180)
6	(9,180)
7	(9,180)
8	(9,180)
9	(9,180)
10	(9,180)
11	(9,180)
12	(9,108)
13	(9,180)
14	(9,180)
15	(9,180)

Calculating the Internal Rate of Return

The sum of the cost elements is presented below. The first column includes the full courseware development cost. The second assigns only 50 percent of this cost to MOS19K30 at Ft. Knox in recognition that the courseware can be used for training MOS19K30 at other bases as well as for training other MOS's. The choice of 50 percent assumes that MOS19K30 at Ft. Knox represents only half of the training that can be done with this courseware. These streams represent the cost of fielding the new technology and the investment cost which must be recovered in cost savings. The cost savings, or benefits, are presented alongside these costs.

Period	Full Cost	Half Cost	Benefits
1	($762,180)	($462,180)	$120,000
2	(9,180)	(9,180)	120,000
3	(9,180)	(9,180)	120,000
4	(9,180)	(9,180)	120,000
5	(9,180)	(9,180)	120,000
6	(609,180)	(309,180)	120,000
7	(9,180)	(9,180)	120,000
8	(9,180)	(9,180)	120,000
9	(137,180)	(137,180)	120,000
10	(9,180)	(9,180)	120,000
11	(609,180)	(309,180)	120,000
12	(9,180)	(9,180)	120,000
13	(9,180)	(9,180)	120,000
14	(9,180)	(9,180)	120,000
15	3,620	3,620	120,000

The analyst as this point has a choice in comparing benefits and costs. A discount rate can be chosen and the present value of the cost stream calculated. Similarly, the present value of the benefit stream can be determined and a benefit-cost ratio constructed. If the ratio is greater than one, benefits exceed costs and vice-versa if the ratio is less than one. Other training technologies might be evaluated in the same manner as computer-assisted instruction and similar benefit-cost ratios constructed. The decision maker will want to choose the technology with the highest benefit-cost ratio for training. However, it can easily be shown that the ranking of training technologies, and even the conclusion as to benefits exceeding costs, can be changed by choosing a different discount rate. Accordingly, sensitivity analysis should be used with this approach allowing the discount rate to vary to determine the effect on the outcome.

A better approach, however, which avoids this problem uses the Internal Rate of Return (IRR). The IRR is the interest rate which sets the present value of the benefits equal to the present value of the costs. It requires no prior assumption about discount rates.

It is determined in an iterative procedure that yields the rate of return on the investment that would just equal the observed stream of benefits. The IRR is based on the sum of benefits and costs as shown below for full and half cost assumptions for courseware development.

Period	Costs (Full) + Benefits	Costs (Half) + Benefits
1	($642,180)	($342,180)
2	110,820	110,820
3	110,820	110,820
4	110,820	110,820
5	110,820	110,820
6	(489,180)	(189,180)
7	110,820	110,820
8	110,820	110,820
9	(17,180)	(17,180)
10	110,820	110,820
11	(489,180)	(189,180)
12	110,820	110,820
13	110,820	110,820
14	110,820	110,820
15	123,620	123,620

Several popular spreadsheet programs for personal computers, such as Lotus 123, provide functions for calculating the IRR. Using Lotus 123, we calculate the IRR for each stream above.

	Costs (Full) + Benefits	Costs (Half) + Benefits
IRR	-8.9%	22.4%

The results show a negative return to the cost of fielding MicroTICCIT when all the courseware development costs are loaded

into MOS19K30. If this small class were the only source of cost savings, it would not pay to invest in MicroTICCIT as a training technology for the M1 Tank. However, when as much as half these costs are spread among other MOS's the return on investment is a healthy 22.4 percent. This illustrates the point of economies of scale in computer-assisted instruction. The larger the range of potential applications for courseware, the further these development costs can be spread making use of the technology more attractive in economic terms.

SUMMARY AND CONCLUSIONS

In this chapter we illustrate how the extended TER model can be used to conduct a CTEA study for computer-assisted instruction on the M1 Abrams Tank. The cost and training effectiveness data used are not drawn from actual studies, but are merely illustrations of how the data might look and be used. The focus is on how to develop the cost data required by the model, and then, how to use these data with measures of training effectiveness to determine if a training technology is cost effective. The model is extended to compare the cost savings of computer-assisted instruction with the investment required to field this technology and to construct a rate of return on the investment.

The analyst is expected to compare this return with the return of other training technologies in choosing a cost minimizing method for task training. The model is well-suited to the selection of training technologies for tasks that are trained on weapons systems whose operation is costly or life threatening. The cost data developed in this chapter illustrate

the economies of scale associated with computer-assisted instruction as a training technology. The approach to developing these data, applying the economic cost concepts presented in the previous chapter, should be of general interest to analysts using this and other CTEA models.

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ABBREVIATIONS

ARI	Army Research Institute for the Behavioral and Social Sciences
BNCOC	Basic Non-Commissioned Officers Course
CTEA	Cost and Training Effectiveness Analysis
DPTM	Directorate of Plans, Training, and Mobilization
IRR	Internal Rate of Return
M1	M1 Abrams Tank
MOS	Military Occupational Specialty
MTER	Marginal Transfer Effectiveness Ratio
OCR	Operating Cost Ratio
POI	Program of Instruction
POL	Petroleum, Oil and Lubricants
STX	Situational Training Exercise
TER	Transfer Effectiveness Ratio
TICCIT	Time Shared Interactive Computer Controlled Information Television
TRADOC	U. S. Army Training and Doctrine Command
TRs	Training Request Forms
TTFA	Training Technology Field Activity

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